M. KIREYEV and A. KOVARSKY

SWITCHGEAR INSTALLATION

A MANUAL FOR INSTALLERS OF ELECTRICAL SWITCHGEAR AND POWER LINES

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М. И. КИРЕЕВ, А. И. КОВАРСКИЙ

МОНТАЖ И ЭКСПЛУАТАЦИЯ
ЭЛЕКТРИЧЕСКИХ СТАНЦИЙ,
ПОДСТАНЦИЙ И ЛИНИЙ ПЕРЕДАЧ

На английском языке

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PART ONE

INSTALLATION OF POWER SYSTEM EQUIPMENT

CHAPTER 1

INSTALLATION WORK

1. Plans and Drawings

Power system equipment is installed to a design which includes circuit and wiring diagrams, layout plans, sectional views and drawings of the various units and components (see Sec. 4).

The plans are supplemented with an explanatory report which gives the necessary design data, a bill of electrical equipment and materials, and a cost estimate covering the equipment, materials and labour.

Before installation work may be started, it is furthermore necessary to have the acceptance reports, specifications and manufacturer's certificates of the equipment to be installed.

Switchgear electricians should first take over the supporting structures built to their specifications by the building contractors, that is, check against the drawings the actual dimensions as well as the number and dimensions of the holes and openings. The results of the inspection should be entered in acceptance reports which are included in the papers required before commencing the installation work.

The required papers should also include work schedules showing arrivals of equipment and materials at the site, planned transfers of the labour force, job schedules for each team, and the requisite mechanisms, fixtures and tools.

Each major item of installation work should be covered by an operation sequence card. Such cards list the various operations to be performed in carrying out a given job, as well as the requisite tools, fixtures and mechanisms, they outline the preferable sequence and techniques.

A card form is shown in Table 1.

Table 1

Operation Sequence Card

For ______________________________

(state job to be carried out)

Operation	Tools, fixtures and mechanisms	Materials	Techniques and procedures

2. Tools and Mechanisms Employed in Installation Work

High-quality tools and mechanisms go a long way towards raising the productivity and efficiency of switchgear electricians.

Each switchgear electrician should be supplied with a kit containing a set of assorted hand tools (Fig. 1). In the U.S.S.R. a typical

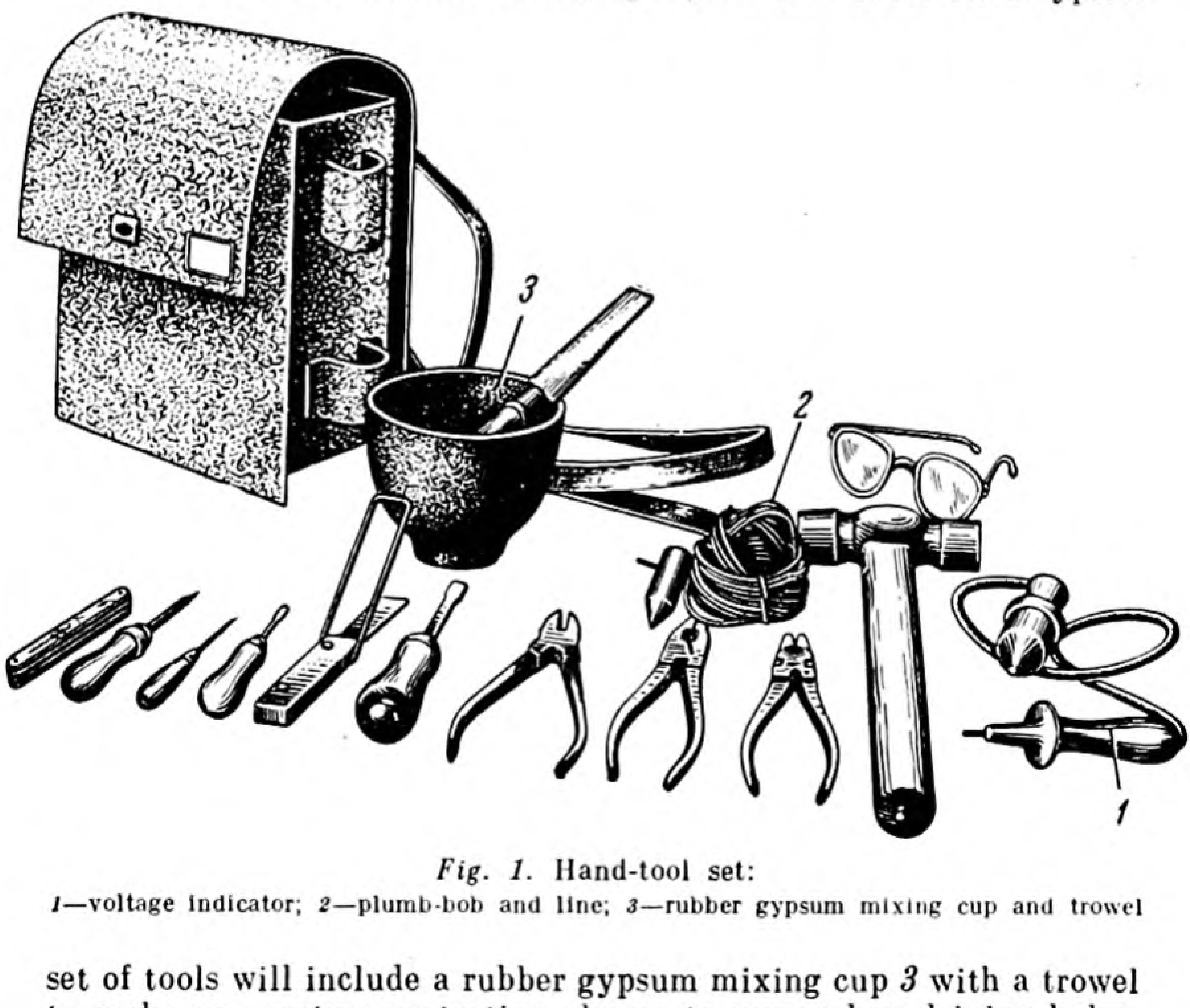


Fig. 1. Hand-tool set:
1—voltage indicator; *2*—plumb-bob and line; *3*—rubber gypsum mixing cup and trowel

set of tools will include a rubber gypsum mixing cup *3* with a trowel to make up mortar; protective glasses to wear when driving holes;

a plumb-bob *2* for marking out; a voltage indicator *1* for use on temporary circuits operating at voltages up to 380 volts.

At present holes in brickwork and concrete are driven by electric drills with carbide-tipped bits (Fig. 2) instead of the unproductive and labour-consuming hammer and chisel.

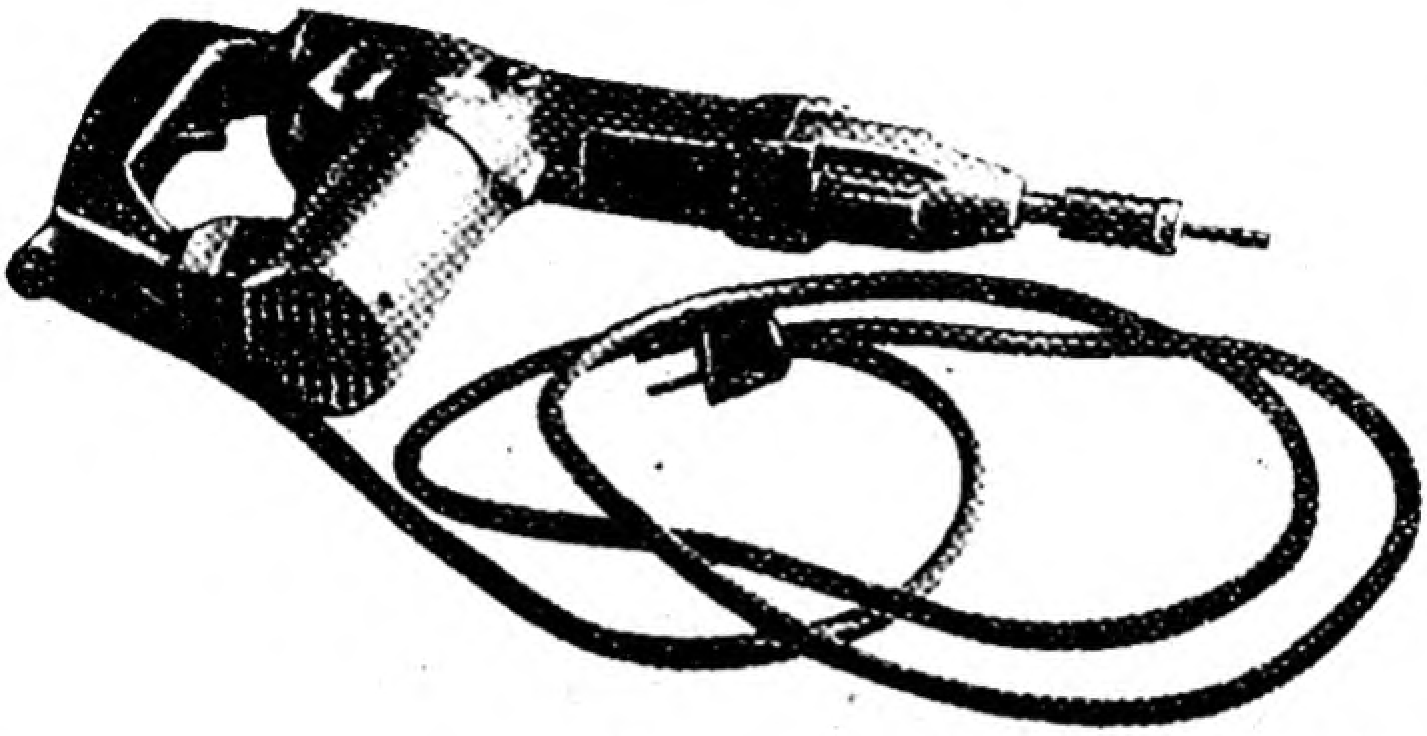


Fig. 2. Electric drill

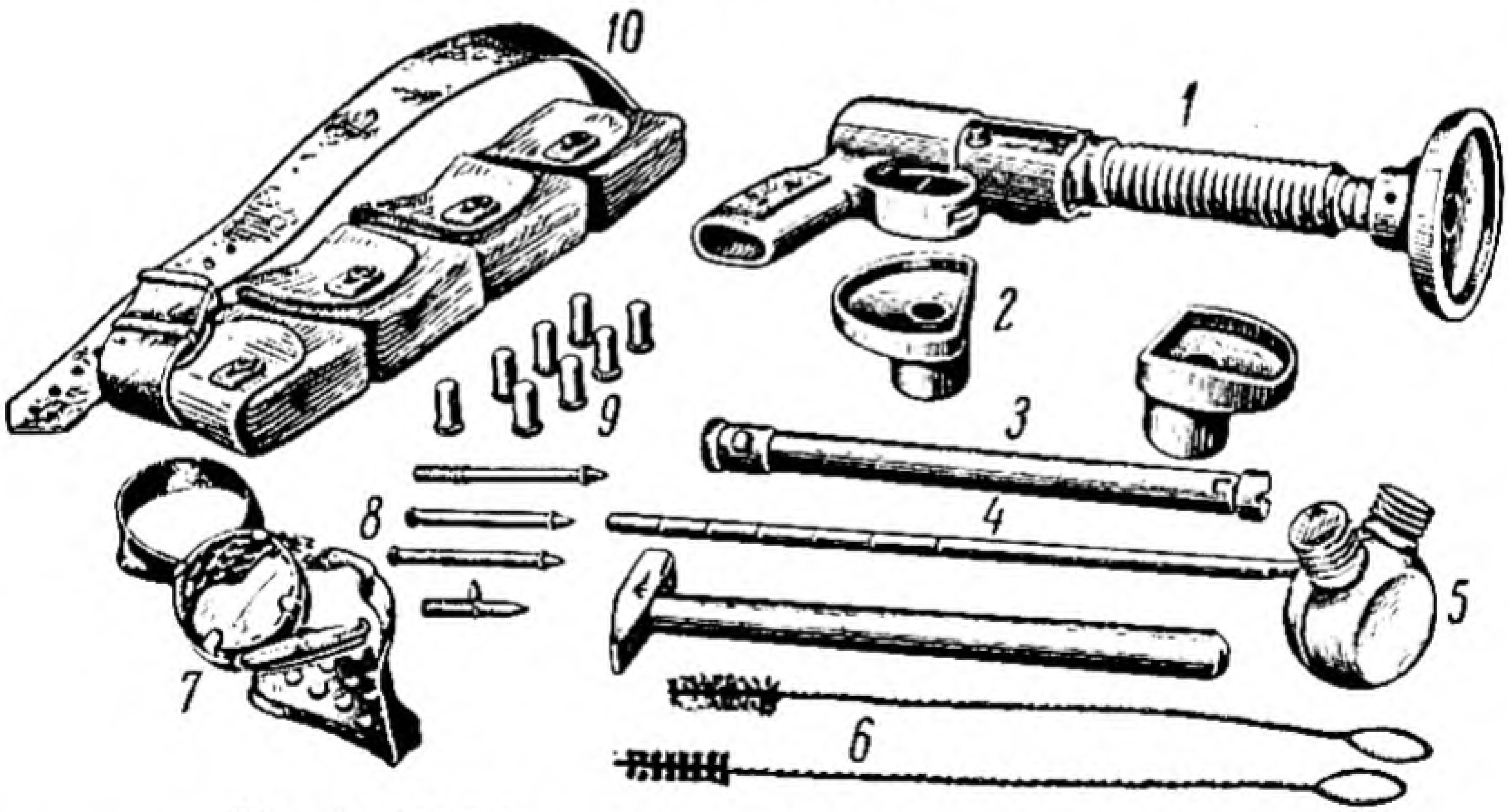


Fig. 3. СМП-1 powder-actuated dowel-driving gun:
1—pistol; *2*—muzzle adapters; *3*—interchangeable barrels; *4*—ramrod; *5*—oil can; *6*—barrel-cleaning brush; *7*—goggles; *8*—dowels; *9*—cartridges; *10*—cartridge belt

Another and a more recent trend has been towards dowel-driving guns exemplified by the СМП-1 type (Fig. 3) powered by a charge of gun powder. The СМП-1 dowel-driving gun, which is a single-charge

breech-loading pistol weighing 3 kg, is furnished complete with two interchangeable gun barrels of 12- and 8-mm bore, a supply of cartridges of different explosive power, studs or dowels, and several muzzle adapters making the gun suitable for work under various conditions.

Today buses are joined and connectors are pressed on cable and wire conductors by means of foot-operated hydraulic presses such as the НГП-7 (Fig. 4) of 7-ton force. The press simplifies and speeds up the work and makes it possible to dispense with tin and lead which would otherwise be necessary to make soldered joints.

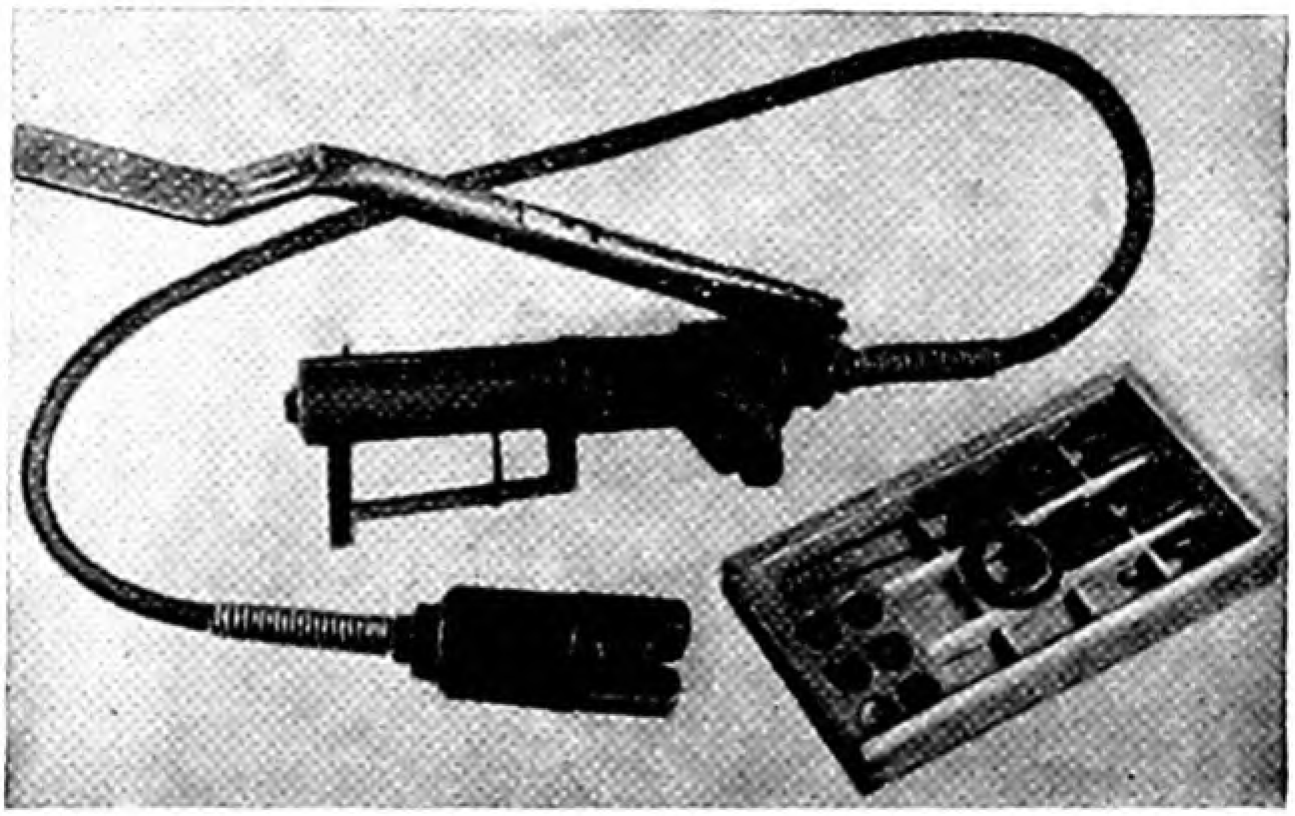


Fig. 4. НГП-7 foot-operated hydraulic press

The installation of any power station or substation involves a good deal of metal working, especially on rolled shapes. For this reason these sites are equipped with universal portable presses, such as the УПП, and press-shears, like the ПН-1.

The УПП universal portable press can cut angles, strip, round and square bars, make 45-, 90-, and 135-degree cuts in the legs of angles, punch holes in steel, copper and aluminium, and stamp small mounting hardware.

The press is driven by a 3.5-kw electric motor. It is able to trim and shape-cut angles measuring up to 60×60×6 mm and strip up to 60×6 mm.

The above press is capable of punching holes up to 60 mm in diameter in steel sheet up to 2 mm thick and holes up to 26 mm in diameter in steel up to 5 mm thick.

The ПН-1 press-shears (Fig. 5) show nearly the same cutting capability.

Angles in sizes up to 45×45×5 mm and steel strip in sizes up to 45×5 mm are cut on a hand-operated lever ПРН-5 press (Fig. 6).

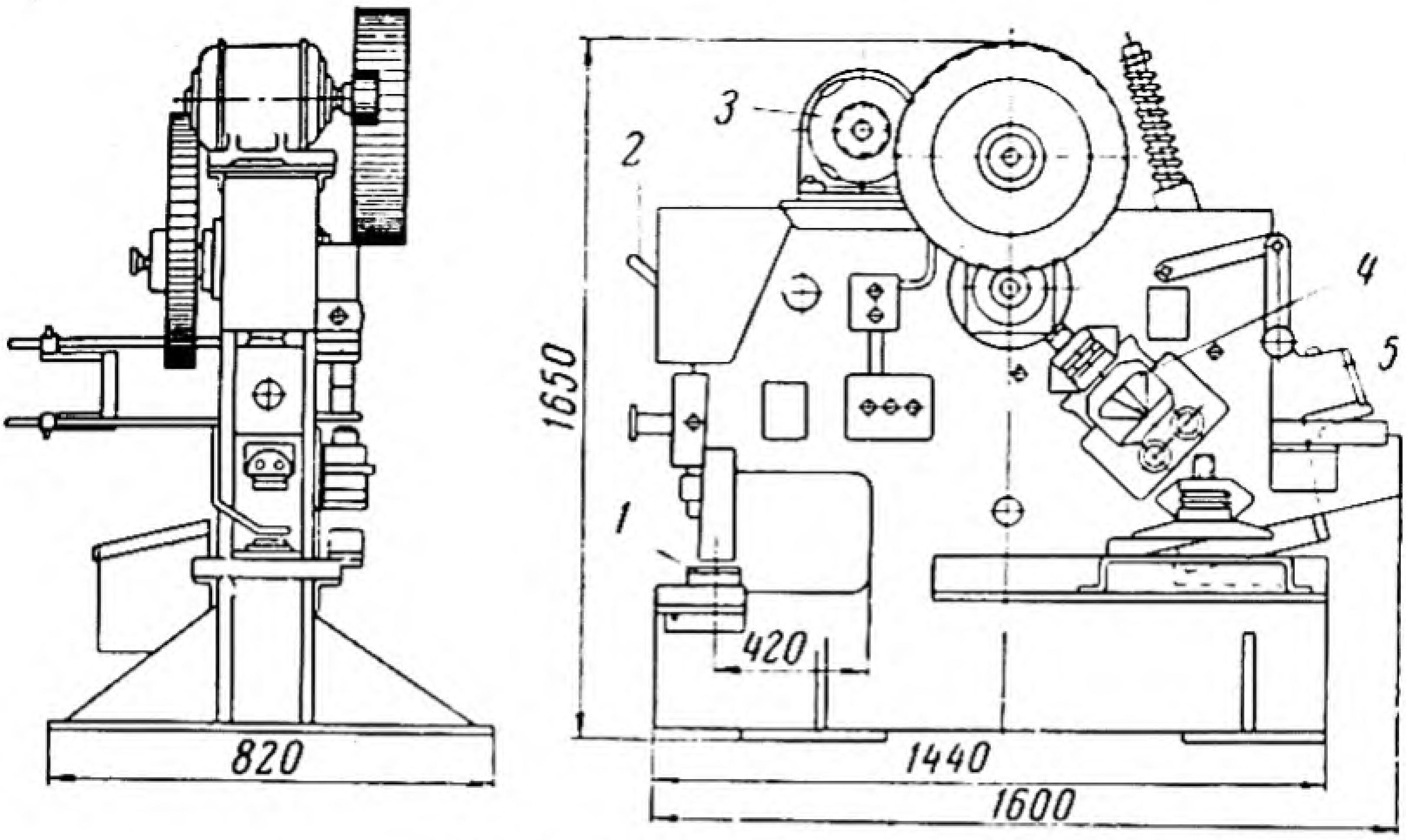


Fig. 5. ПН-1 press-shears:

1—mechanism for hole punching and mounting hardware stamping; *2*—work stroke control lever; *3*—electric motor; *4*—shear knife for transverse cutting of rolled shapes; *5*—die for making cuts in legs of angles

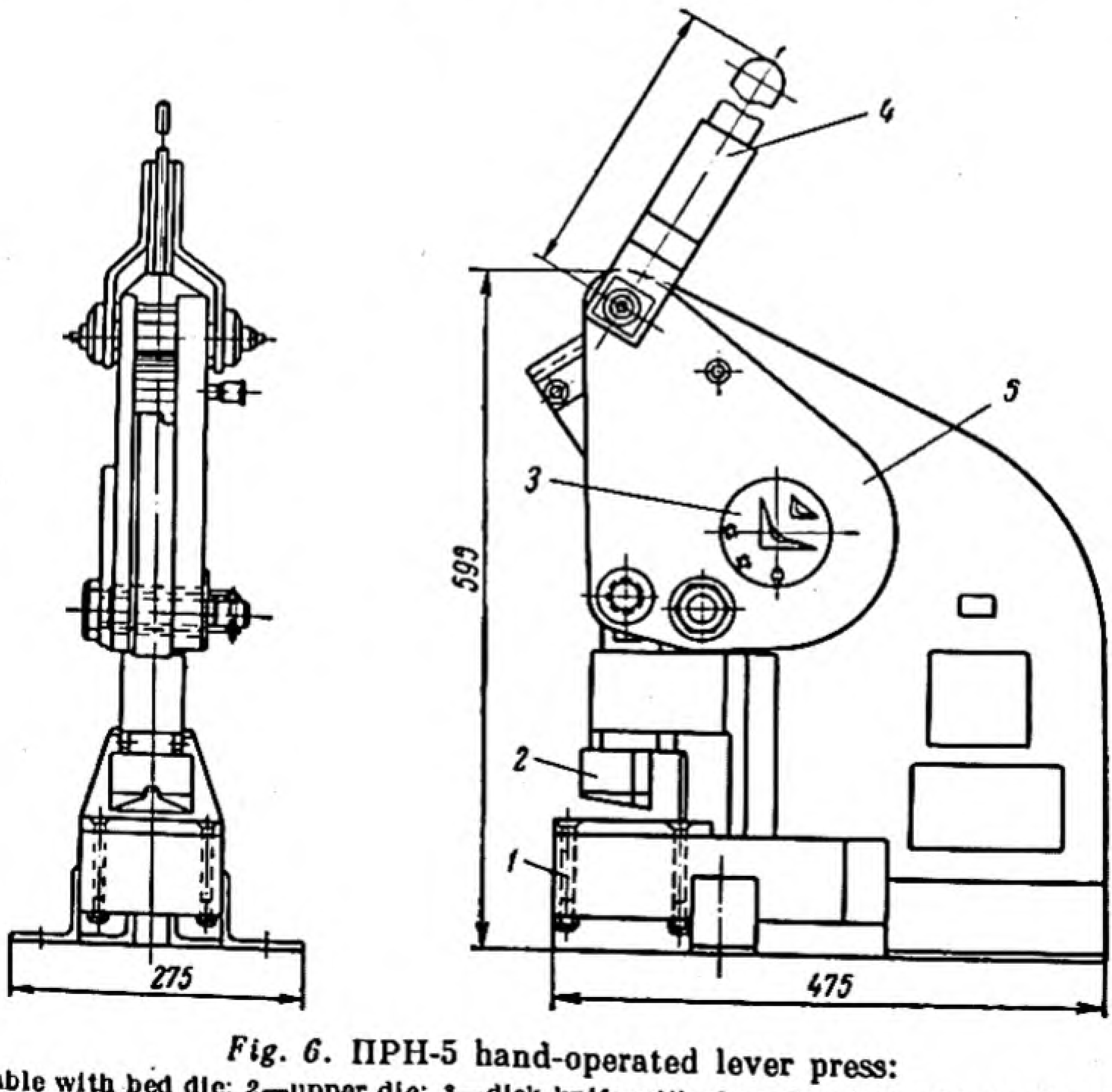


Fig. 6. ПРН-5 hand-operated lever press:

1—table with bed die; *2*—upper die; *3*—disk knife with shaped and round holes for shearing angles and rounds; *4*—operating lever; *5*—moving cheek

This press is employed on sites where the work is relatively small in volume or where the bulk of bench work is carried out in centralised workshops.

Holes in parts of relatively intricate shape are drilled on electric drilling machines. Fig. 7 shows a Type 2150 single-spindle, vertical drilling machine capable of drilling holes up to 50 mm in diameter. This machine is driven by a 2-kw electric motor.

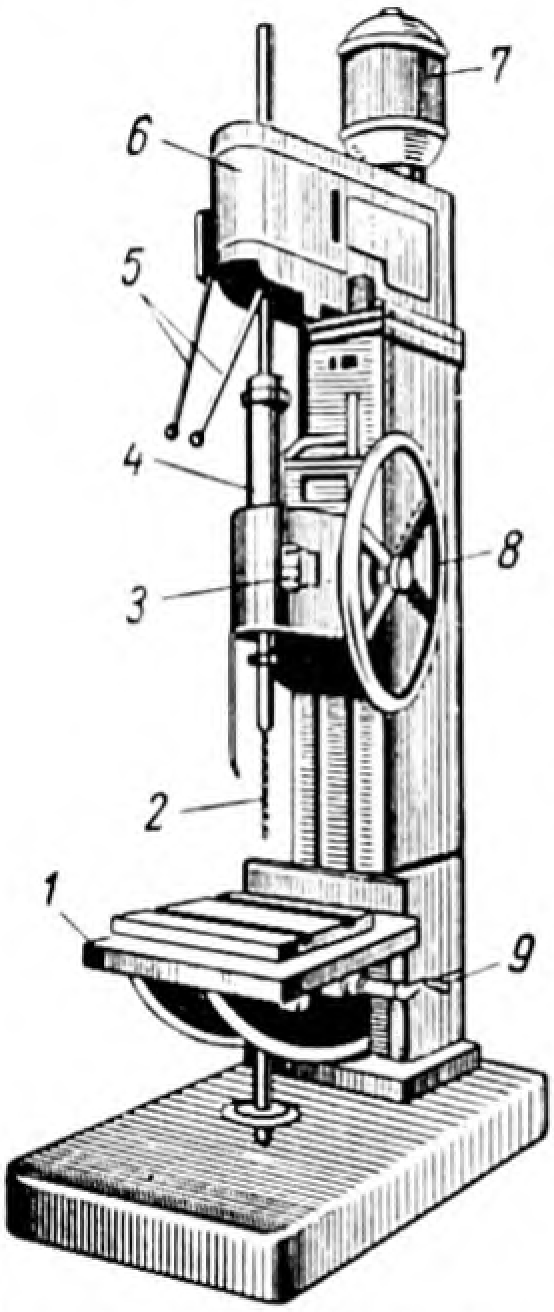


Fig. 7. Type 2150 single-spindle, vertical drilling machine:

1—table; *2*—drill; *3*—start push-button; *4*—spindle; *5*—operating handles; *6*—gear box; *7*—electric motor; *8*—drill feed hand-wheel; *9*—table-lifting handle

Metal can be cut on friction saws (Fig. 8). For its operation, a friction saw depends on the heat generated by a disk revolving at a high speed and pushed against the metal to be cut. Friction cutting is quite efficient. One of the disadvantages of this method is the burrs formed on the cut because of the high temperatures developed. However, it is a relatively simple matter to remove the fins on a rough grinding wheel, like the T-2 shown in Fig. 9.

The Э3С grinder used for sharpening and dressing chisels, drills, etc., is similar in design to the T-2 grinder.

A job frequently met with in the installation of power system equipment is the handling of heavy-weight units. This calls for sufficiently large truck cranes, such as the K-51 of 5 tons lifting capacity at a 3.8-metre boom reach or the K-32 with a lifting capacity of 3 tons at a boom reach of 2.5 metres.

This purpose can also be served by hand-operated hoists rated from 0.5 to 7.5 tons and electric winches for loads up to 20 tons (Fig. 10). Also widely used are various blocks and tackle arrangements, and chain or worm-gear hoists which can handle loads up to 10 tons (Fig. 11).

A large percentage of the installation time is spent on bending aluminium strip into busbars which serve to distribute the currents in a station or substation. These strips have to be bent to various angles. To that end various types of busbar benders are employed, and among them the hydraulic busbar bender shown in Fig. 137.

Welding constitutes an essential element in modern installation practice, and installation sites, as a rule, always have welding stations (Fig. 12).

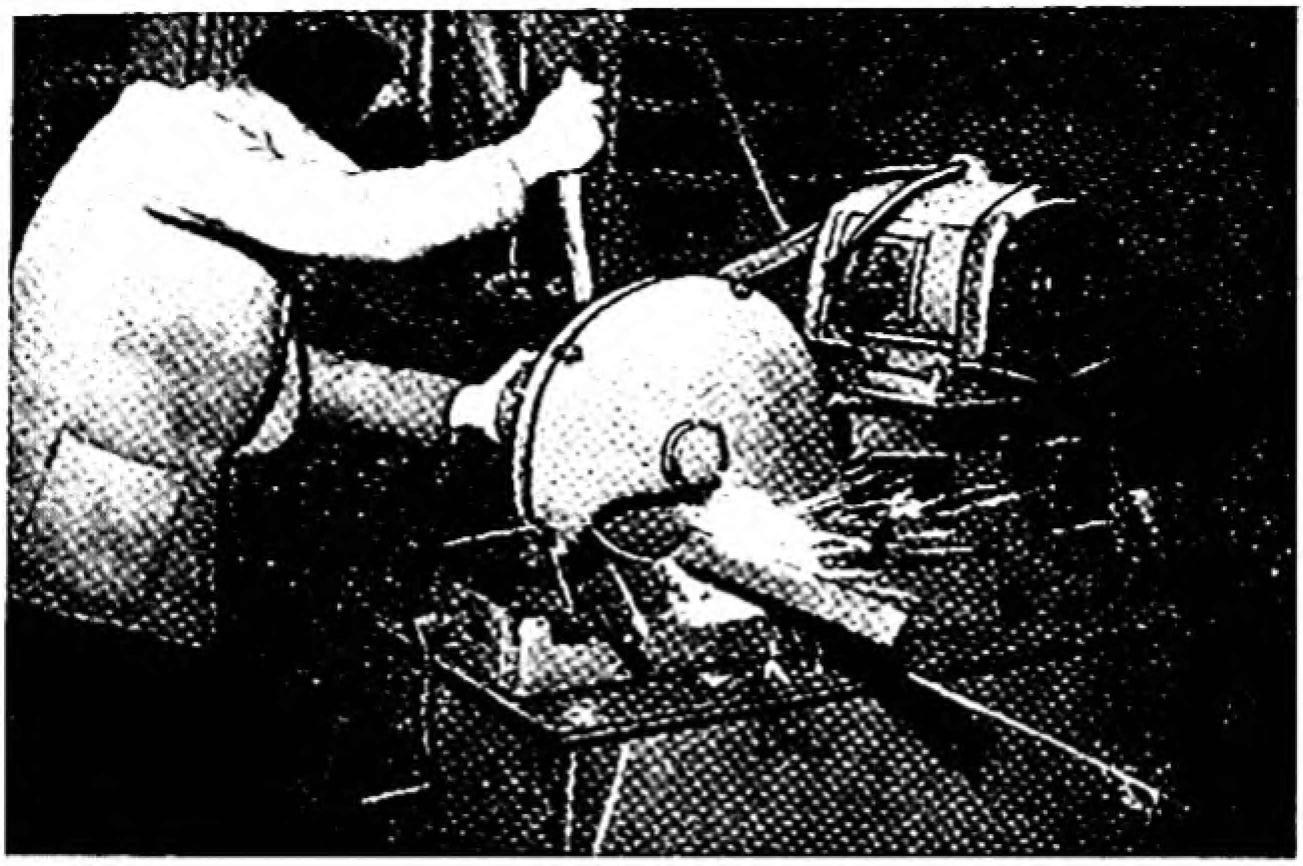


Fig. 8. Friction saw

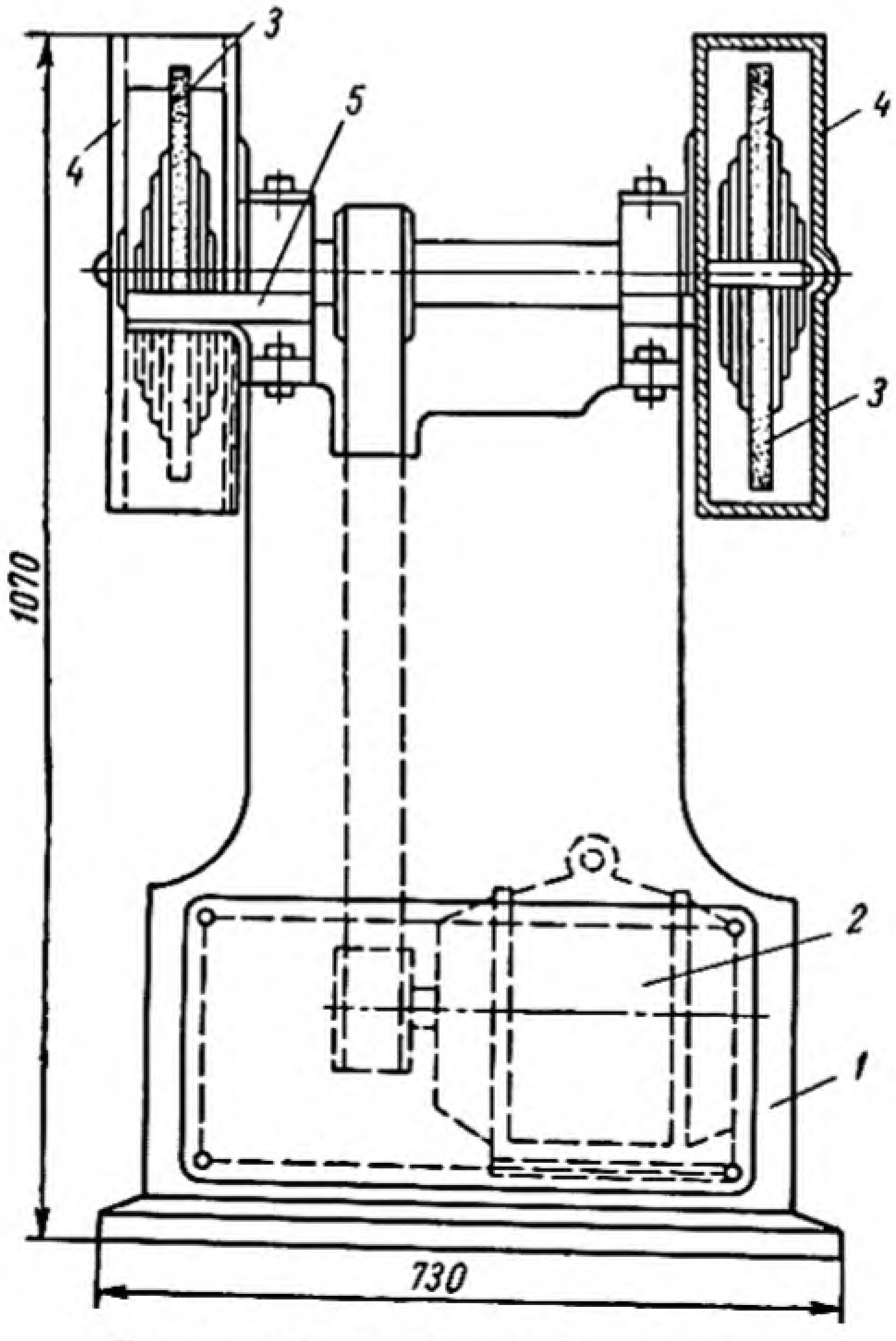


Fig. 9. T-2 rough grinding wheel:
1—cast-iron frame; *2*—electric motor; *3*—grinding wheel; *4*—protective hood; *5*—support for work during grinding

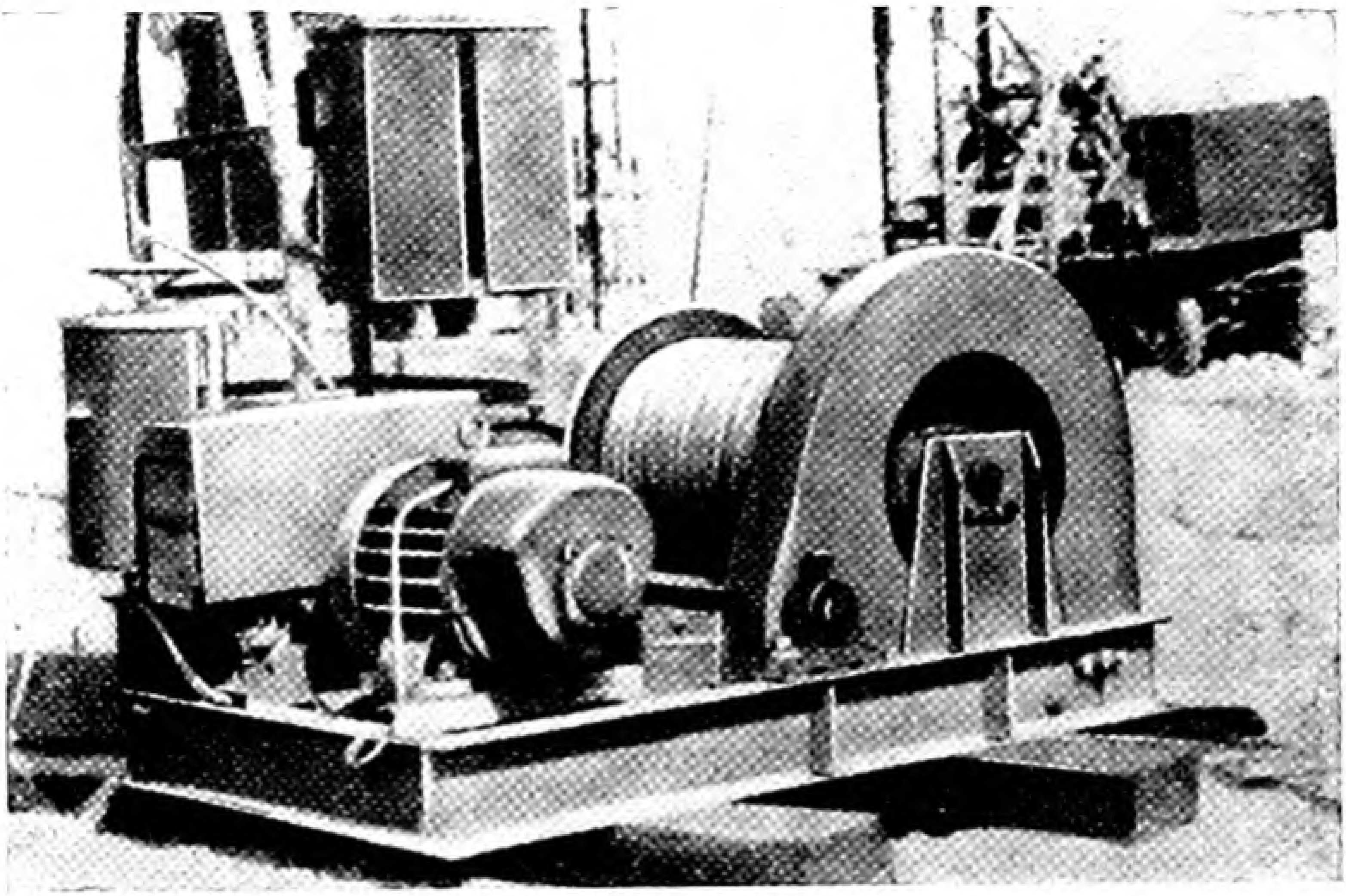


Fig. 10 Electric winch

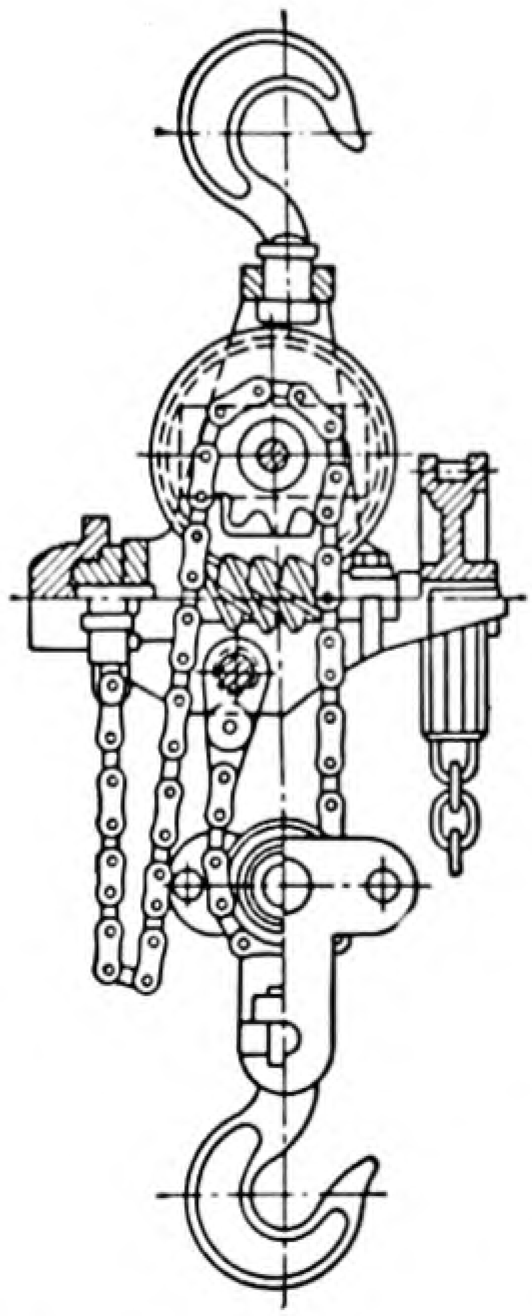


Fig 11. Worm-gear hoist

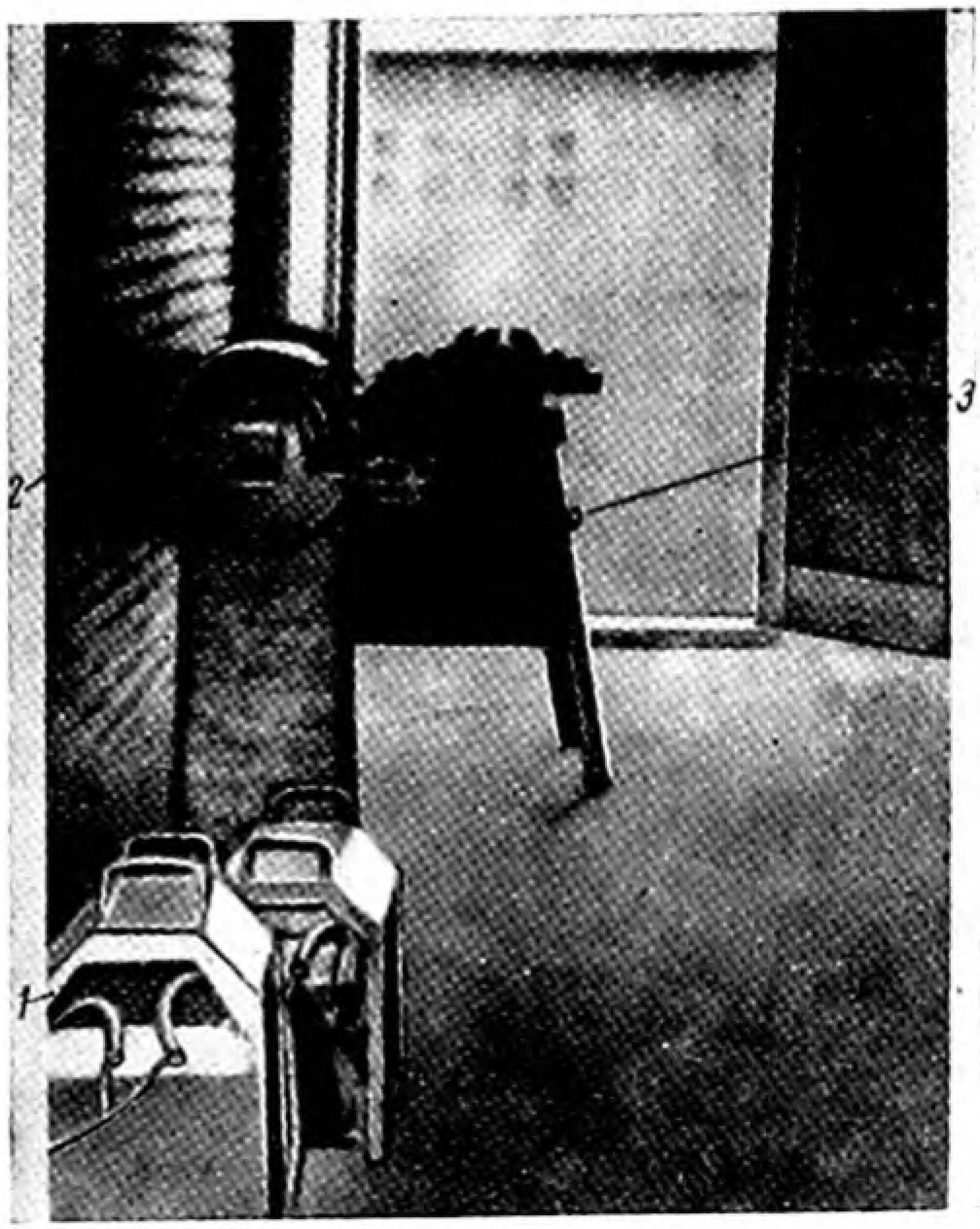


Fig. 12. Welding station in a workshop:
1—welding transformer; 2—grind wheel; 3—work bench

CHAPTER 2

SUBSTATION SWITCHGEAR

3. Types of Substations

Substations are a vital link in any power system which delivers electric power from a generating station down to consumers.

From the pictorial diagram in Fig. 13, it is easy to see that on its way to the loads the electric power generated by a power station passes through a whole series of substations.

Switchgear installations may be subdivided into:

(1) indoor switchgear installations, in which the equipment is placed within a building;

(2) outdoor switchgear installations, in which the equipment is mounted in the open air.

Indoor switchgear is most often designed for 6- to 10-kv service. If, however, the ambient atmosphere is laden with aggressive impurities, such as metal-corroding gases and fumes, conductive dust, etc., the substation will be of the indoor type for voltages up to and including 110 kv.

In some cases the switchgear is installed within a building made of brick or concrete (the cellular type) and the electrical equipment is mounted directly on the structural parts of the substation building or room (Fig. 14). In other cases, the substation metal framework for the switchgear (the cubicle type) is prepared in workshops and delivered to the site ready for erection (Fig. 15).

At the present time, ever wider use is made of indoor substations made up of prefabricated front-serviced units (the KCO type) (Fig. 16), or metal-clad truck-type units (Fig. 17) (the KPY type). With these types of switchgear the assembly and wiring is transferred completely to factories, which fact leads to economy in materials, improved quality, and reduced erection time.

Outdoor switchgear installations are generally designed for service at from 35 kv to as high as 500 kv.

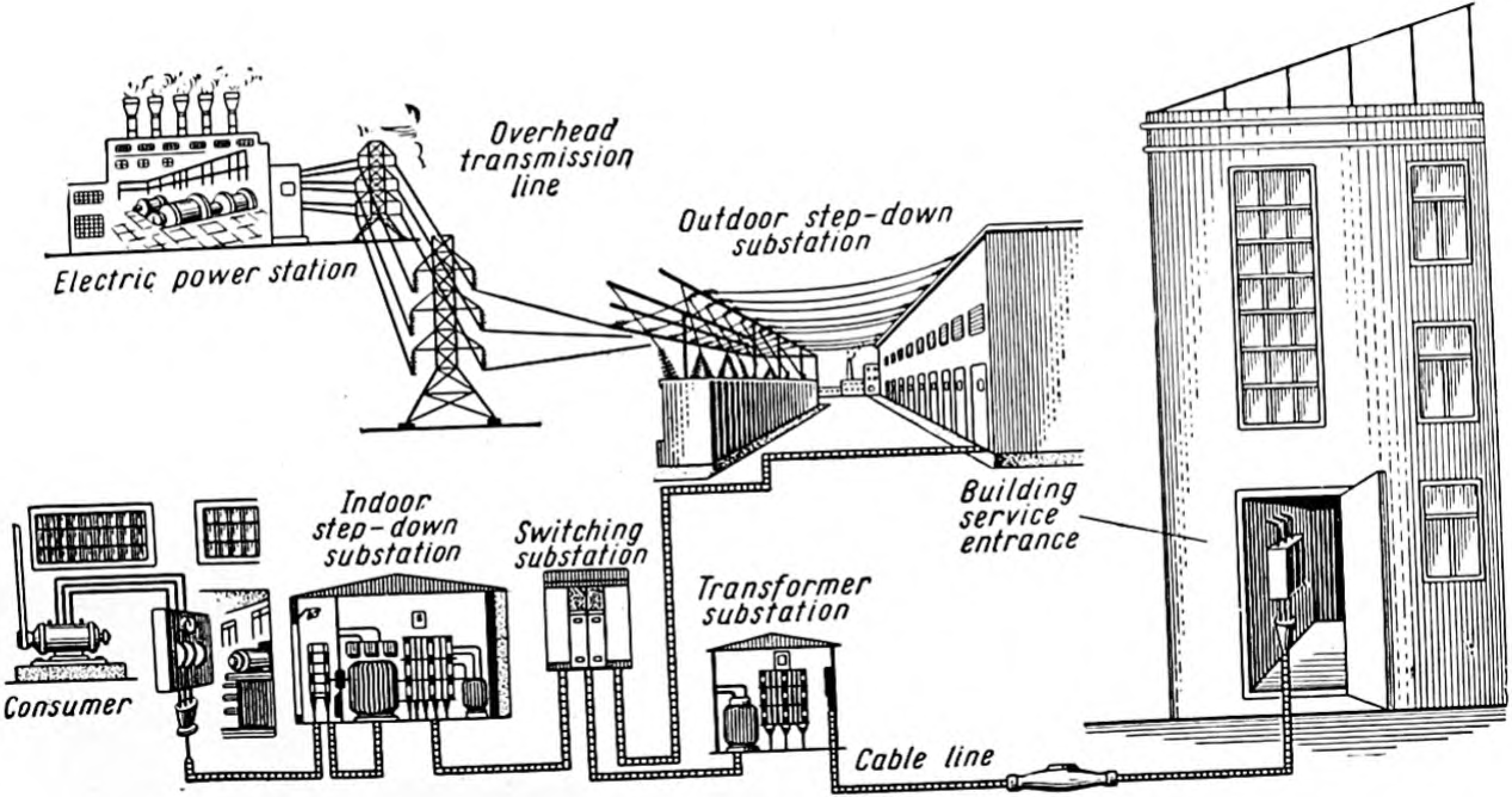


Fig. 13. Power transmission and distribution from a generating station

Suburban transformer substations and rural substations, however, supplying small rural areas may use outdoor switchgear of the 6- to 10-kv class.

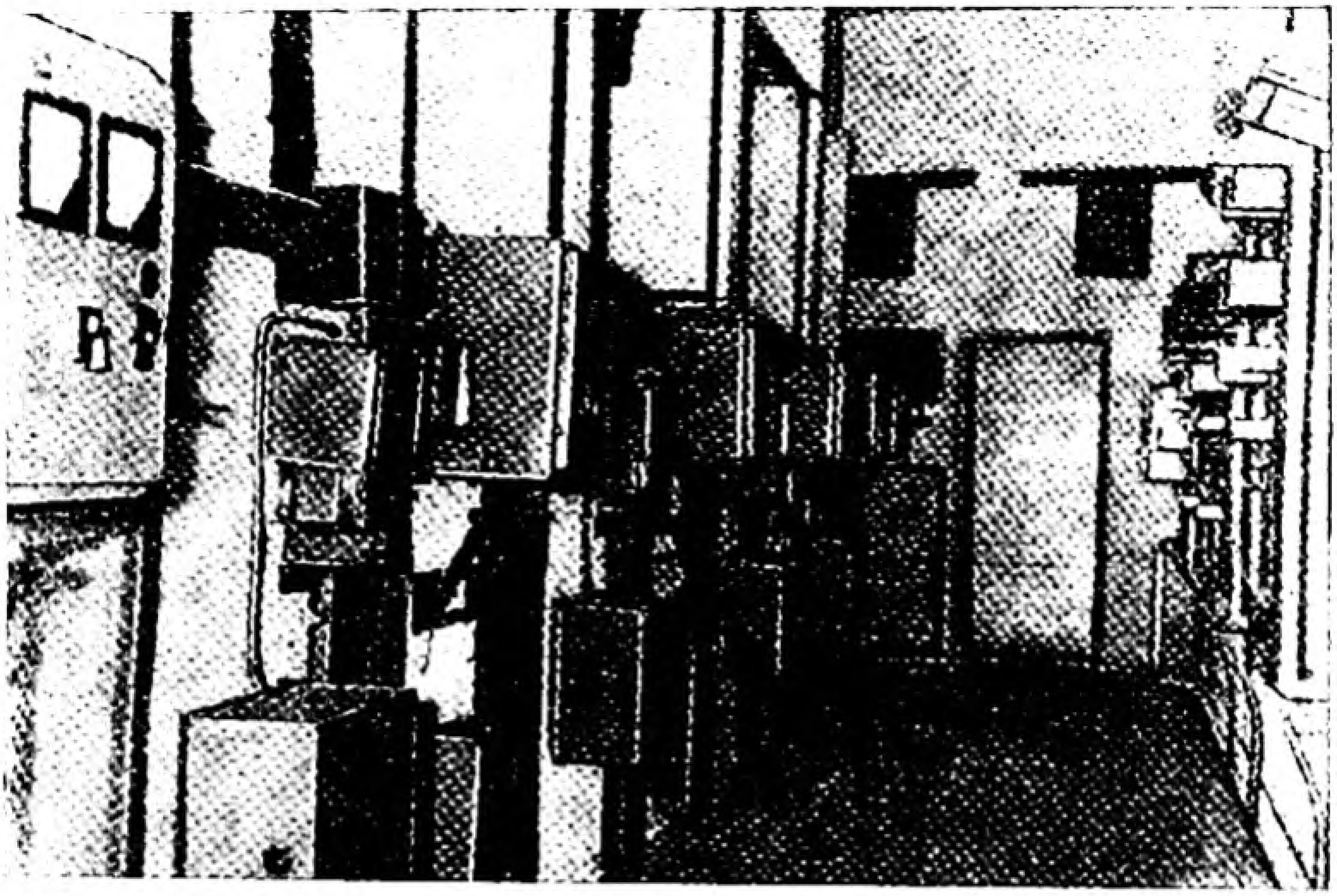


Fig. 14. Equipment directly mounted on structural parts in the control aisle of substation

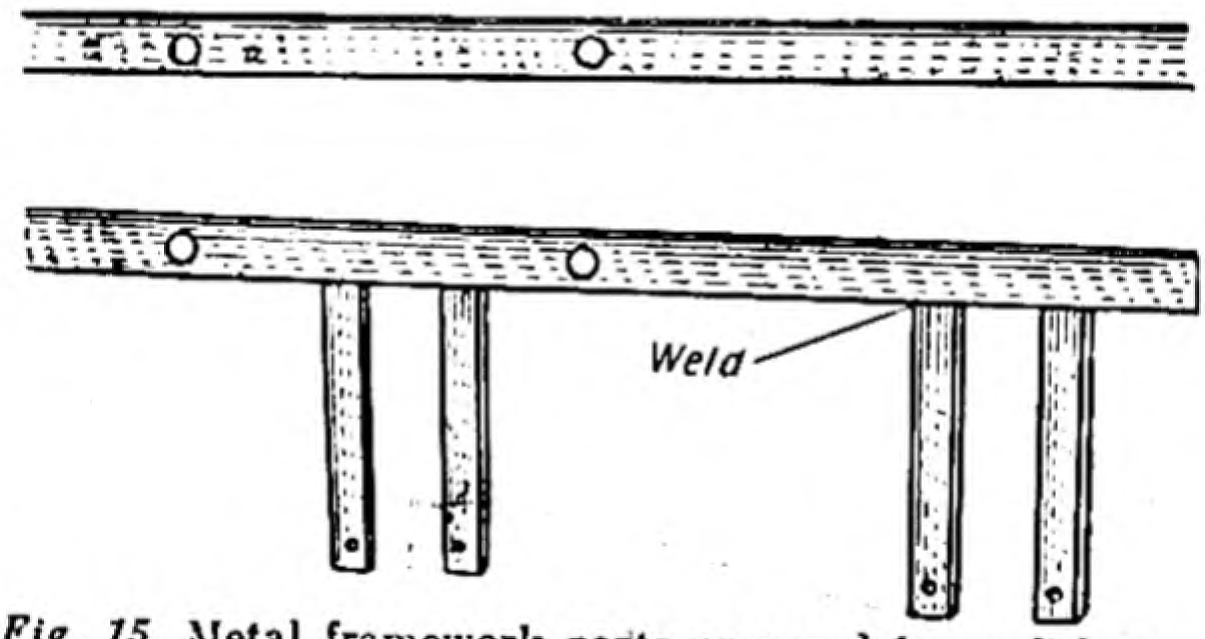


Fig. 15 Metal framework parts prepared in workshops

Outdoor substations may be of the "low" type or of the "high" type. In the former type the equipment is arranged in one horizontal plane or level, while in the latter type, on several levels. In the Soviet Union, outdoor switchgear is mainly of the low type, as it is more convenient to operate and service (Figs 18 and 19).

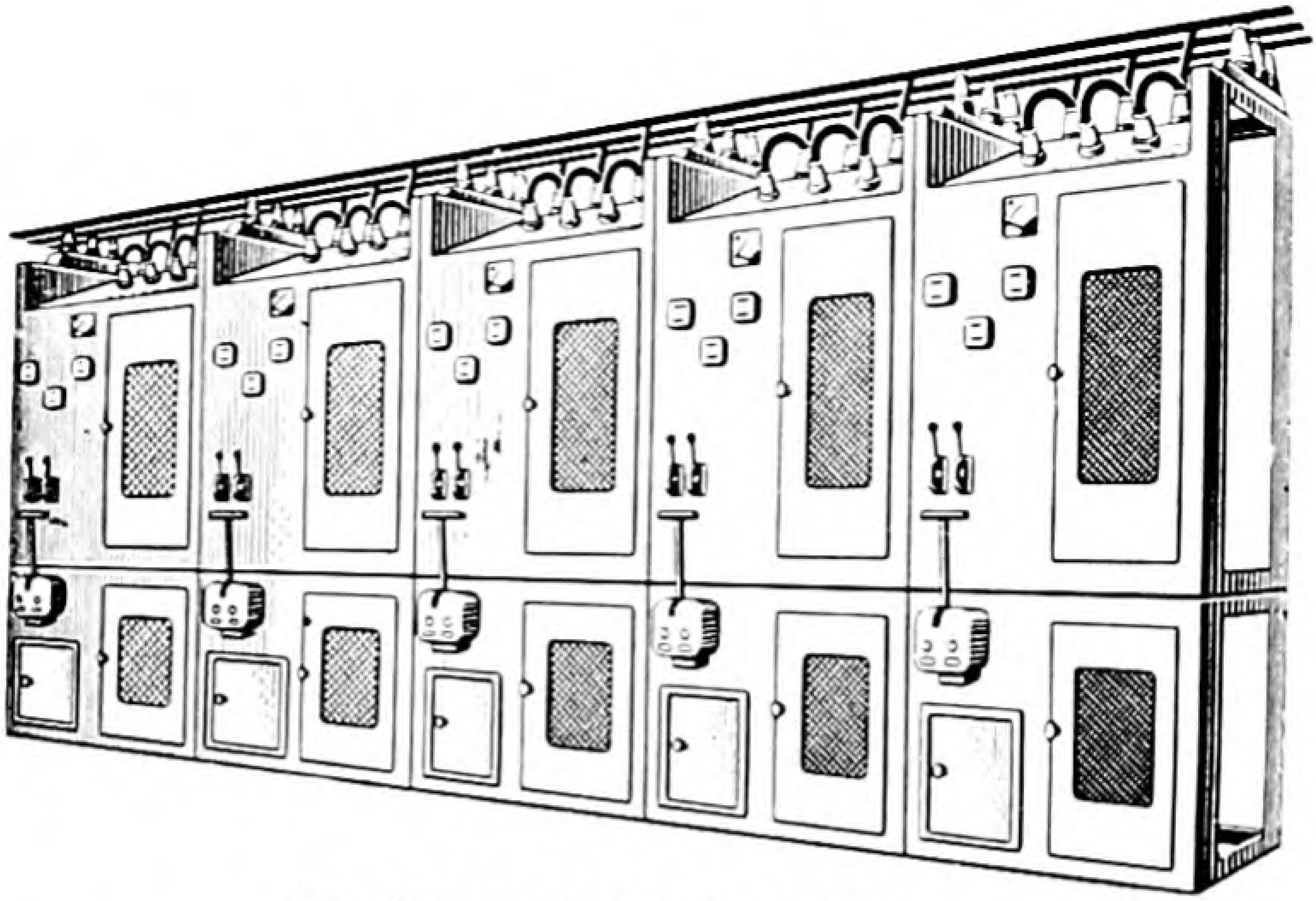


Fig. 16. КСО units for a substation

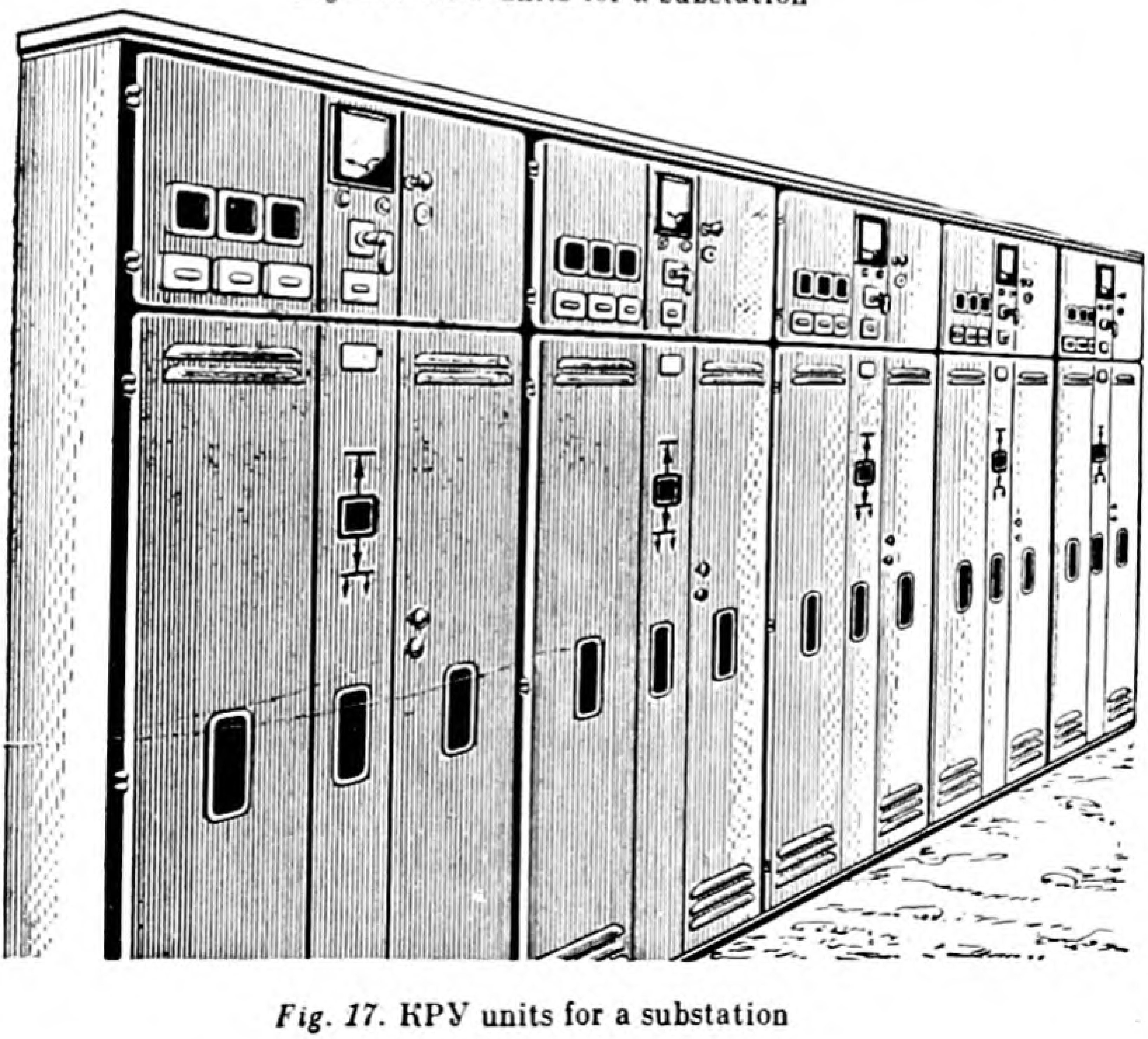


Fig. 17. КРУ units for a substation

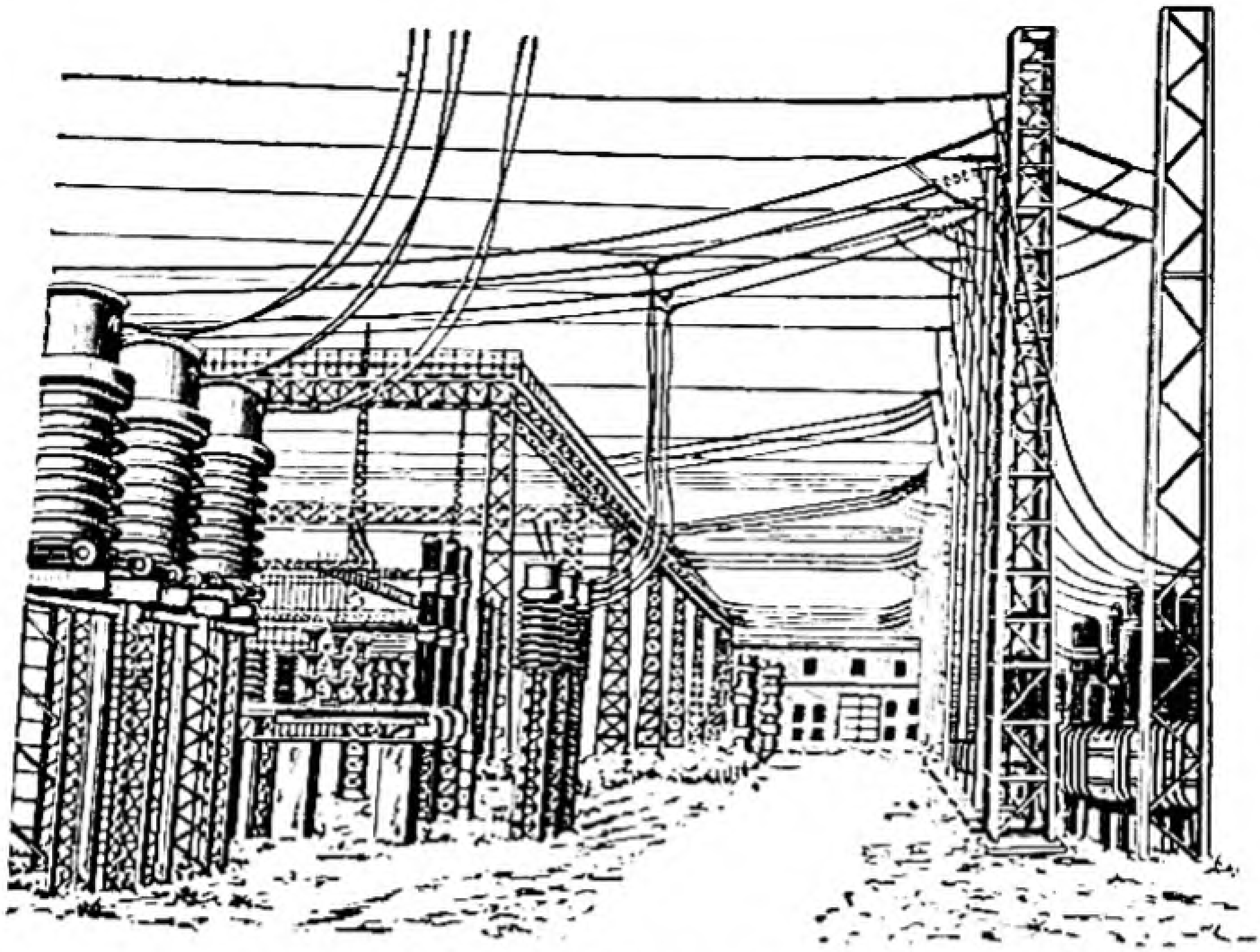


Fig. 18. 220-kv outdoor substation

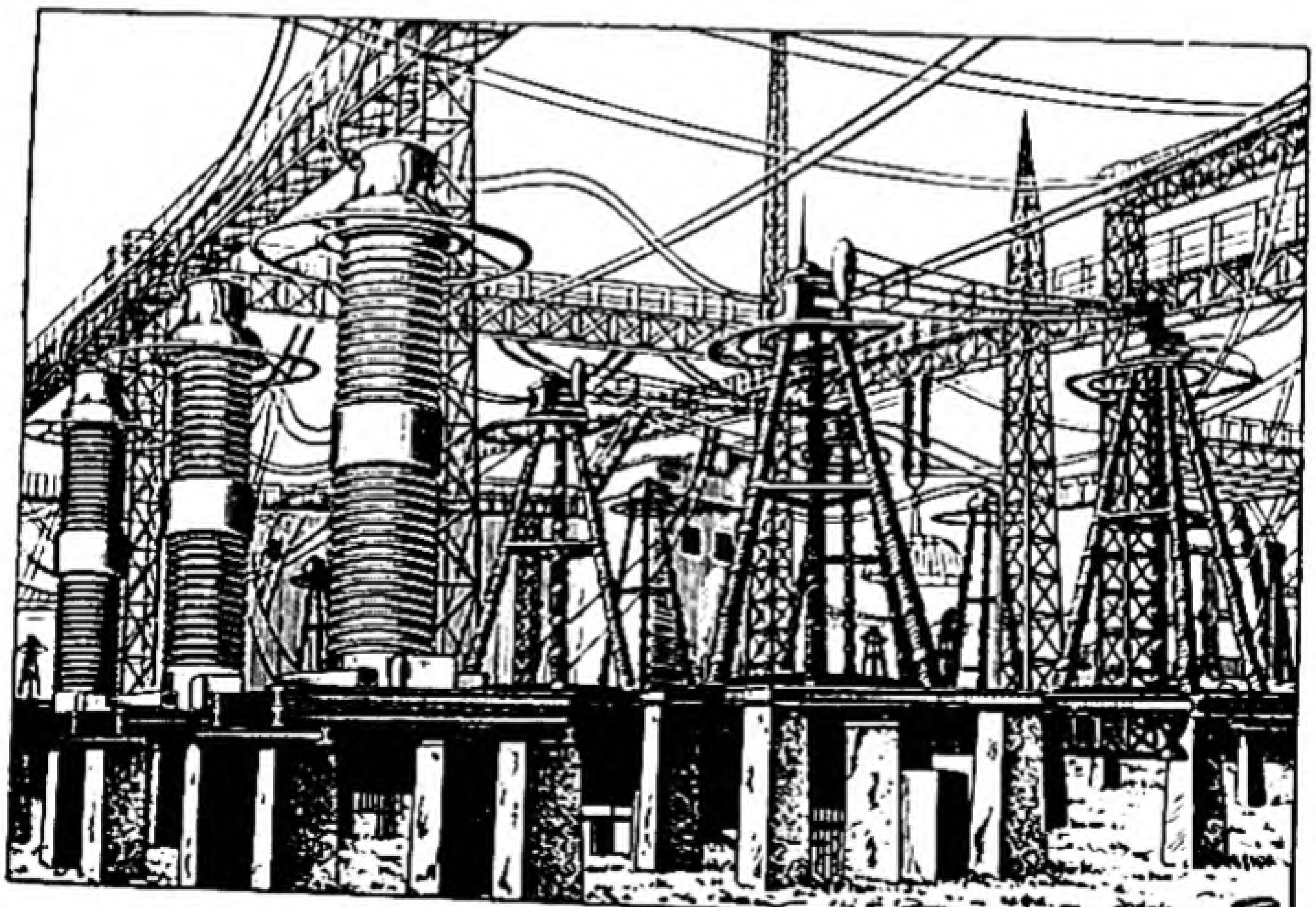


Fig. 19. View of 500-kv outdoor substation

Recent practice has been to use factory-assembled metal-clad outdoor switchgear units (the КРУН type), such as shown in Fig. 20. They are available for voltages up to 35 kv inclusive, and designs have been developed for 110-kv service.

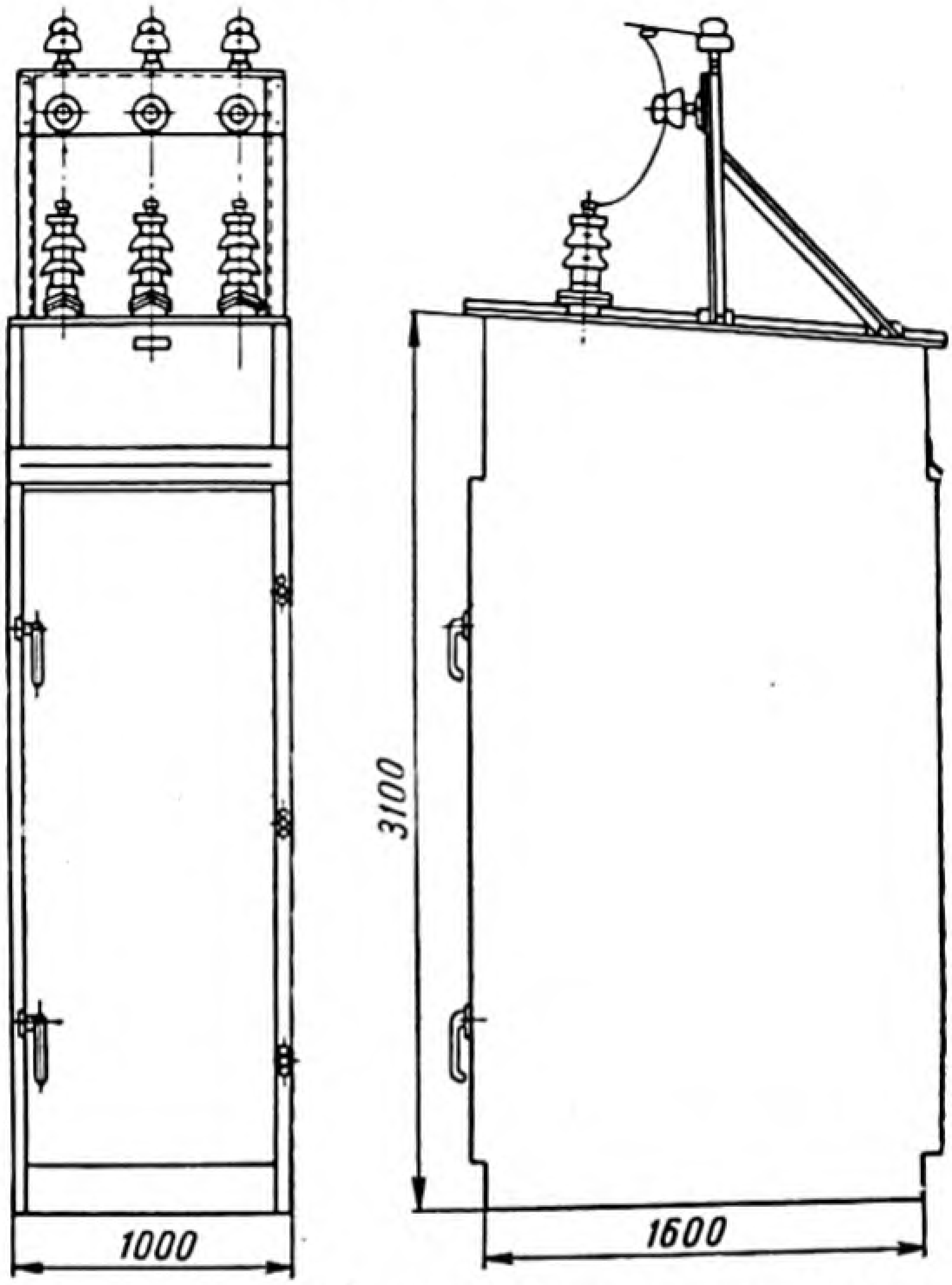


Fig. 20. КРУН metal-clad 10-kv outdoor switchgear unit

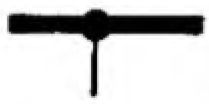
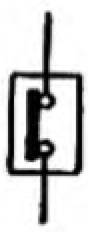
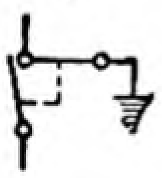
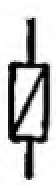
Factory-assembled metal-clad outdoor switchgear reduces in-situ wiring-up, and capital outlay, while improving workmanship and cutting down erection time.

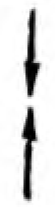
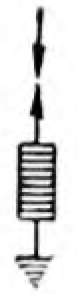
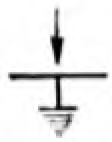
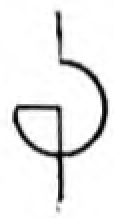
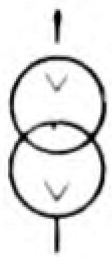
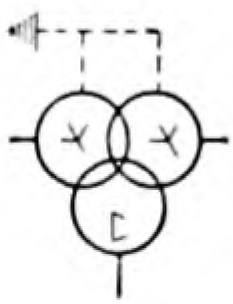
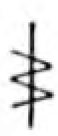
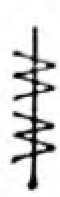
4. Main Connections and Diagrams

Diagrams of primary power connections. These connections are usually shown by what are called single-line diagrams on which one line represents all three phases. The pieces of equipment on these diagrams are represented by conventional symbols (Table 2) in the relative position they will be erected.

Table 2

Conventional Symbols Used in Diagrams of Main Connection Schemes

Symbol	Name
	Buses
	Bus tap-off (tee-off)
	Cable termination
	Isolator (disconnecting switch)
	Load-breaking isolator with arc control device
	Circuit breaker with arc control devices
	Isolator (disconnecting switch); single-pole, with earthing blade and mechanical interlock
	Plug-in connection in withdrawal-type equipment
	Fuse

Symbol	Name
	Arrester (surge diverter) (general symbol)
	Valve-type arrester
	Earthing spark gap
	Reactor
	Three-phase transformer, with star-star connected windings
	Two single-phase instrument voltage potential transformers, open-delta connected
	Instrument voltage potential transformer, three-phase, three-winding, two windings star connected, with brought-out and earthed neutrals; and third winding open-delta connected
	Instrument current transformer with one secondary winding
	Instrument current transformer with two secondary windings

At modern power stations and substations the following arrangements of switching connections are in use:

(a) the single-bus system;

(b) the single sectionalised bus scheme;

(c) the double-bus scheme.

The single-bus scheme (Fig. 21) is used primarily in low-voltage or single-unit stations and substations with relatively few feeders.

The single sectionalised bus scheme (Fig. 22) is used in low and medium power capacity switchgear installations when several sources supply power to the buses. With this system each bus section is connected to one power source and to a group of feeders, which arrangement noticeably raises continuity of power supply. The bus sections can operate both independently and in parallel, for which purpose bus-sectionalising circuit breakers are placed between them.

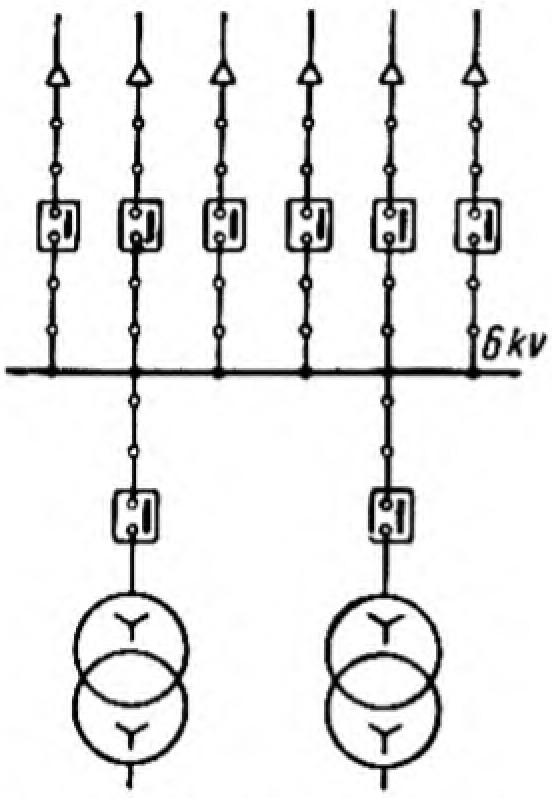


Fig. 21. Substation with single-bus system

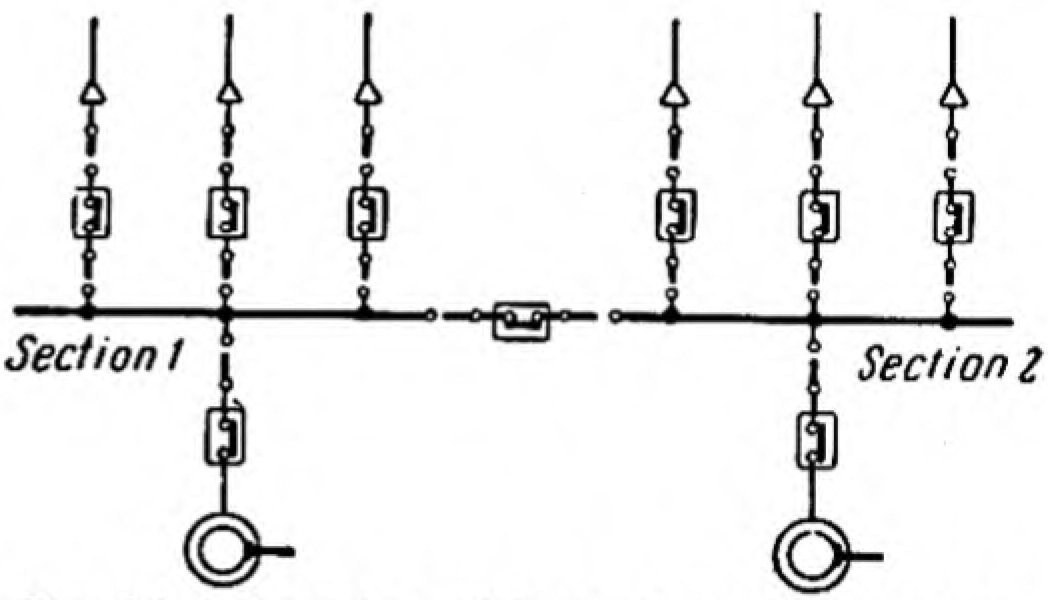


Fig. 22. Substation with single sectionalised bus scheme

The double-bus system (Fig. 23) is used in large power stations and substations in which the switchgear scheme must provide for the connection of a great number of lines or feeders. In some cases the double-bus system can have one of its buses sectionalised, the second bus serving as a spare or transfer one to be used in cases of repairs and emergency. Then it is called the main-and-transfer bus system (Fig. 24).

This arrangement affords bus maintenance without power and feeder disconnection and permits bus coupler breaker maintenance with only one bus set going out.

The above scheme, moreover, reduces the duration of outage due to bus failure to the time needed for a transfer to the spare bus.

The double-bus scheme with both buses nonsectionalised may be designed to have both buses in continuous service. To effect interconnection between them, a bus coupler circuit breaker is provided.

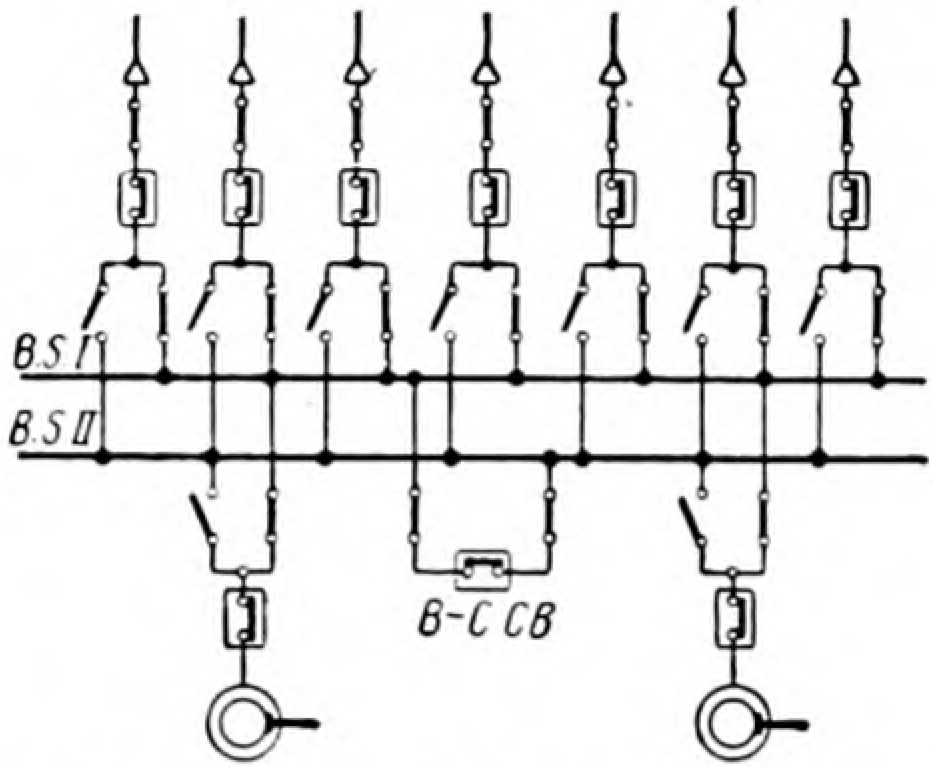


Fig. 23. Substation with double-bus system:
BS I—bus system I; *BS II*—bus system II; *B-C CB*—bus coupler circuit breaker

In modern systems supplying power for large industrial centres the trend is to bring the high transmission voltage closer to the load with the least possible number of intermediate voltage transforma-

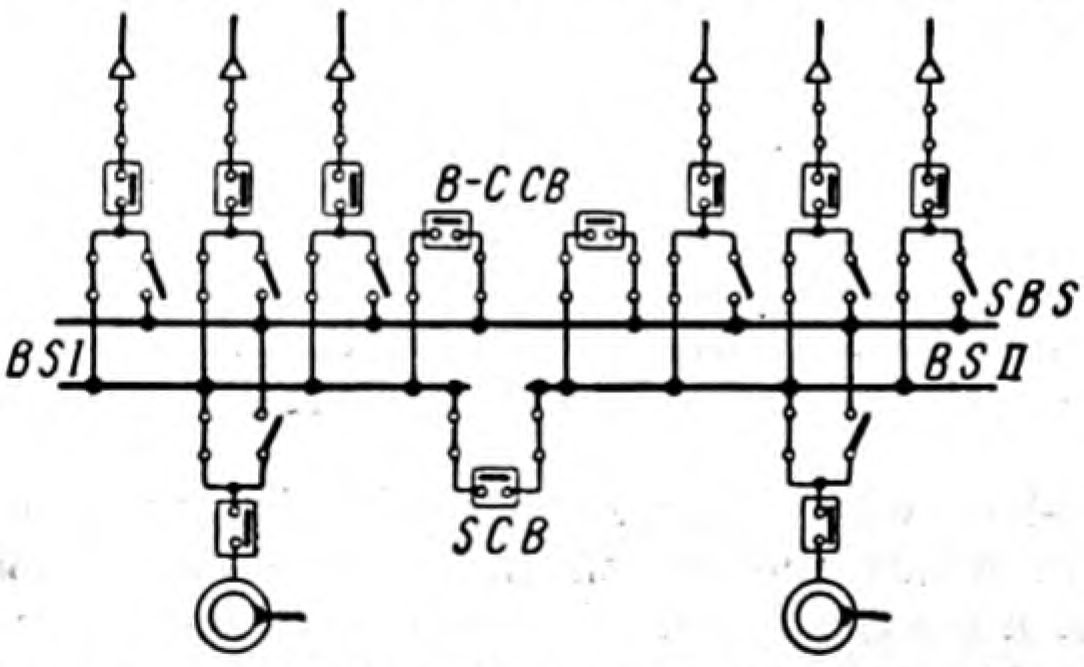


Fig. 24. Double-bus scheme with one system sectionalised:
BS I—bus system I (operating); *BS II*—bus system II (operating); *SBS*—spare (reserve) bus system; *B-C CB*—bus coupler circuit breaker; *SCB*—sectionalising circuit breaker

tions and switching. Such a system of power supply is based on a unit scheme in which a unit consists of a line (overhead or cable) and a transformer.

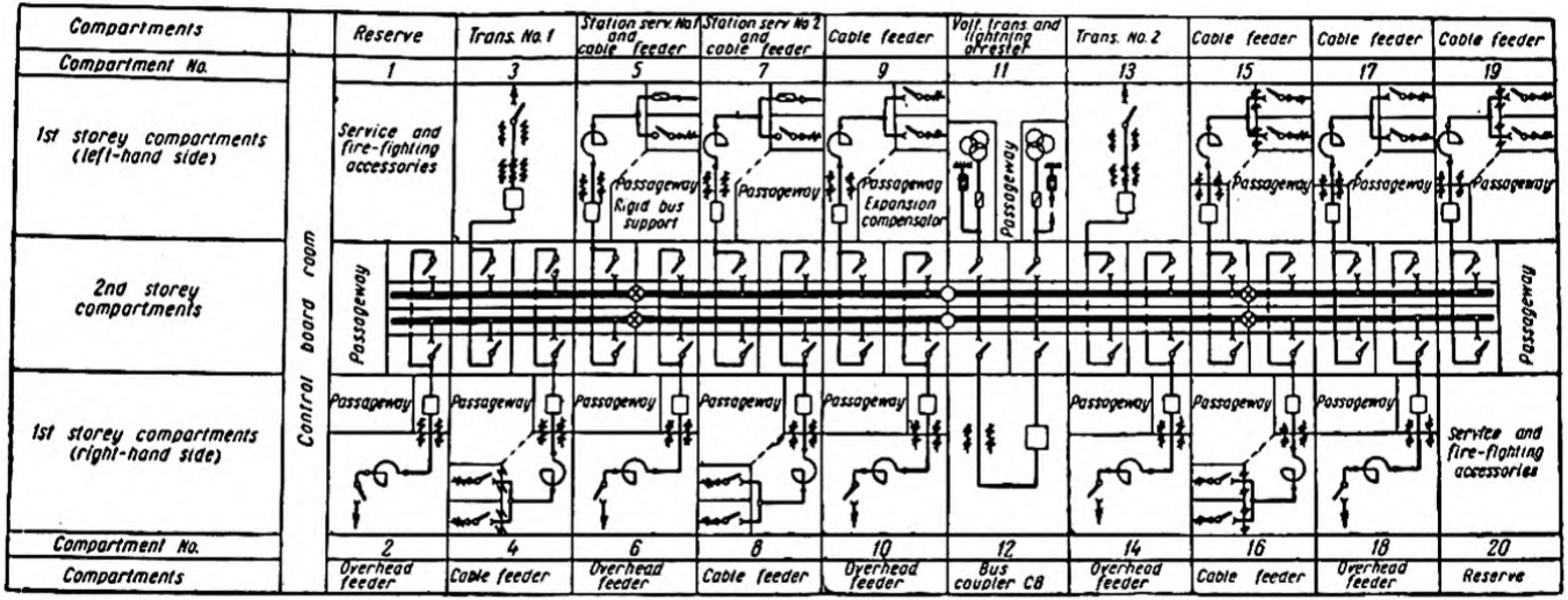


Fig. 25. Substation layout diagram

The arrangement of the equipment in an indoor switchgear structure is shown in layout diagrams (Fig. 25). A layout diagram shows the outline of the switchgear rooms and the floor space allotted to the various pieces of equipment in block form. Layout diagrams are not drawn to scale, do not represent the dimensions of the structure and cannot supplant detailed installation drawings. However, layout diagrams make it easier to understand the installation drawings and are used when drawing up bills of the electrical equipment needed for the installation.

Installation drawings are drawn to scale. They are the working drawings to which the electricians work. An example of an installation drawing for the layout diagram shown in Fig. 25 can be seen in Fig. 26.

For outdoor substations, the arrangement of the equipment is given in layout plans and sectional elevation drawings (Fig. 27).

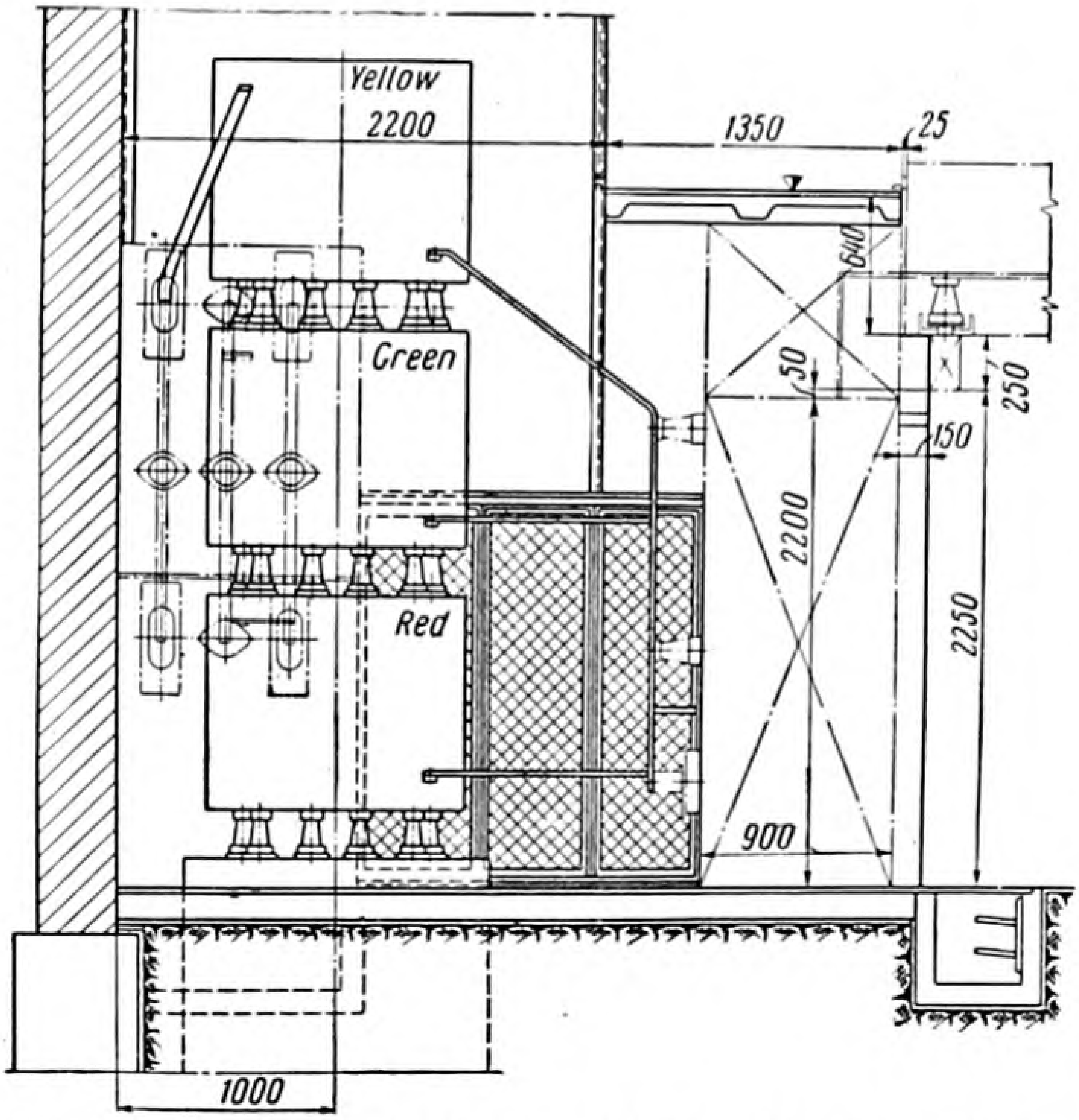


Fig. 26. Installation drawing for cable line cell (with reactor)

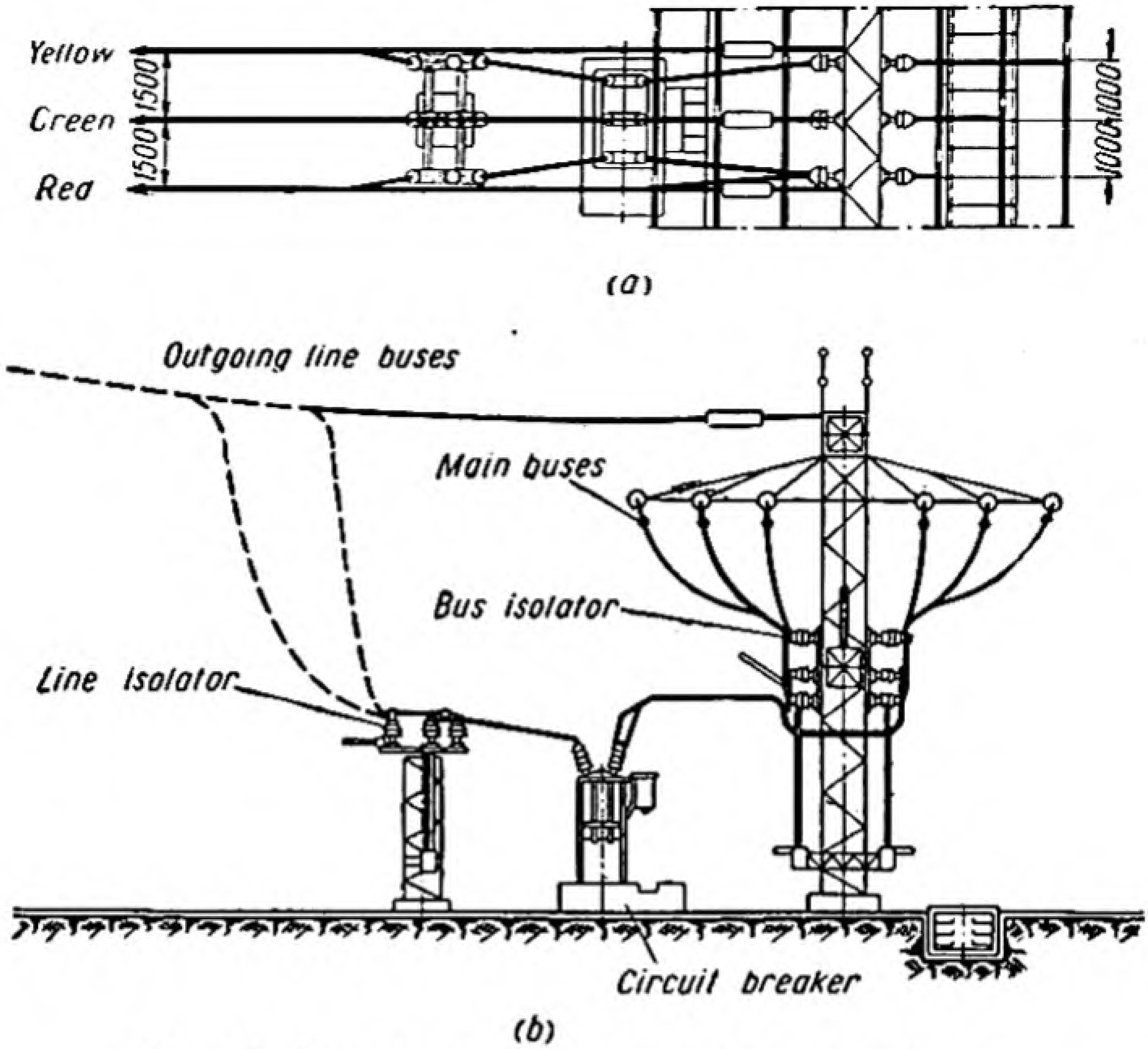


Fig. 27. Outgoing line in an outdoor substation:
a—plan view; *b*—sectional elevation

Diagrams of secondary or control connections show the relative arrangements of the various instruments, relays, apparatus and other circuit elements with the aid of conventional symbols (Table 3).

Secondary or control connections can be shown with simplified schematic, full schematic and wiring diagrams.

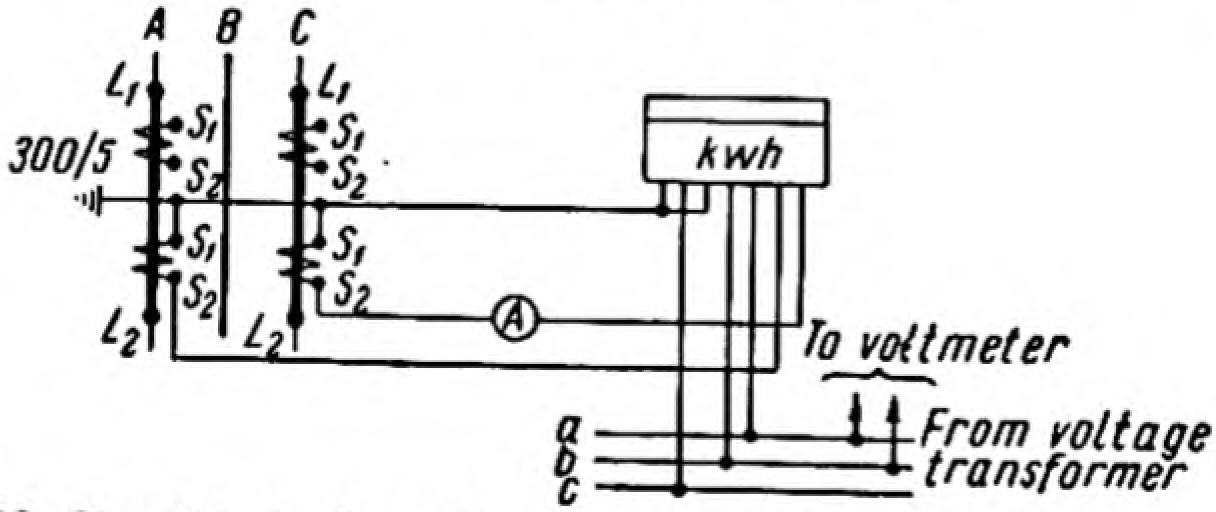
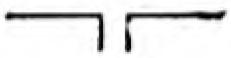
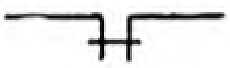
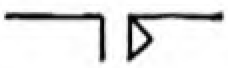
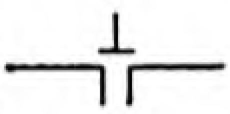
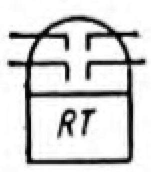
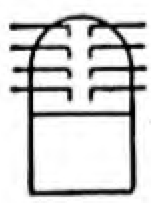


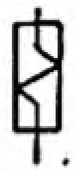
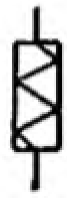
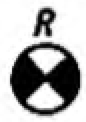
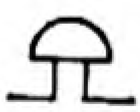
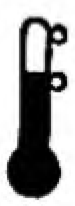
Fig. 28. Simplified schematic diagram, metering-indicating circuit

Simplified schematic diagrams (Fig. 28) serve only to interpret the principle of operation and relative functions of the instruments,

Table 3

Conventional Symbols Employed in Diagrams of Secondary or Control Connections

Symbol	Circuit element
	Normally-open (NO) contact
	Normally-closed (NC) contact
	Normally-open contact with time delay in opening
	Normally-open contact with latch operation and hand reset
	Instantaneous current relay, with one normally-open contact
	Instantaneous voltage relay, with one normally-open contact
	Inverse-time current relay, with one normally-open contact
	Power relay, with one normally-open and one normally-closed contact
	Time-delay relay, with instantaneous normally-open contact and time delay in opening
	Auxiliary relay, with several contacts
	Signal relay, with hand reset

Symbol	Circuit element
	Trip coil (electromagnet with series winding)
	Trip coil (electromagnet with shunt winding)
	White signal lamp
	Red signal lamp
	Green signal lamp
	Emergency signal lamp
	Electric howler or siren
	Electric bell
	Two-way switch
	Mercury-contact thermometer

relays and apparatus. They are drawn for the separate sections of a bus system and are used for making up full schematic and wiring diagrams.

Full schematic diagrams (Fig. 29) give the secondary or control connections of the entire bus system. They show the functional relationships of the protective relays, automatic controls and alarm

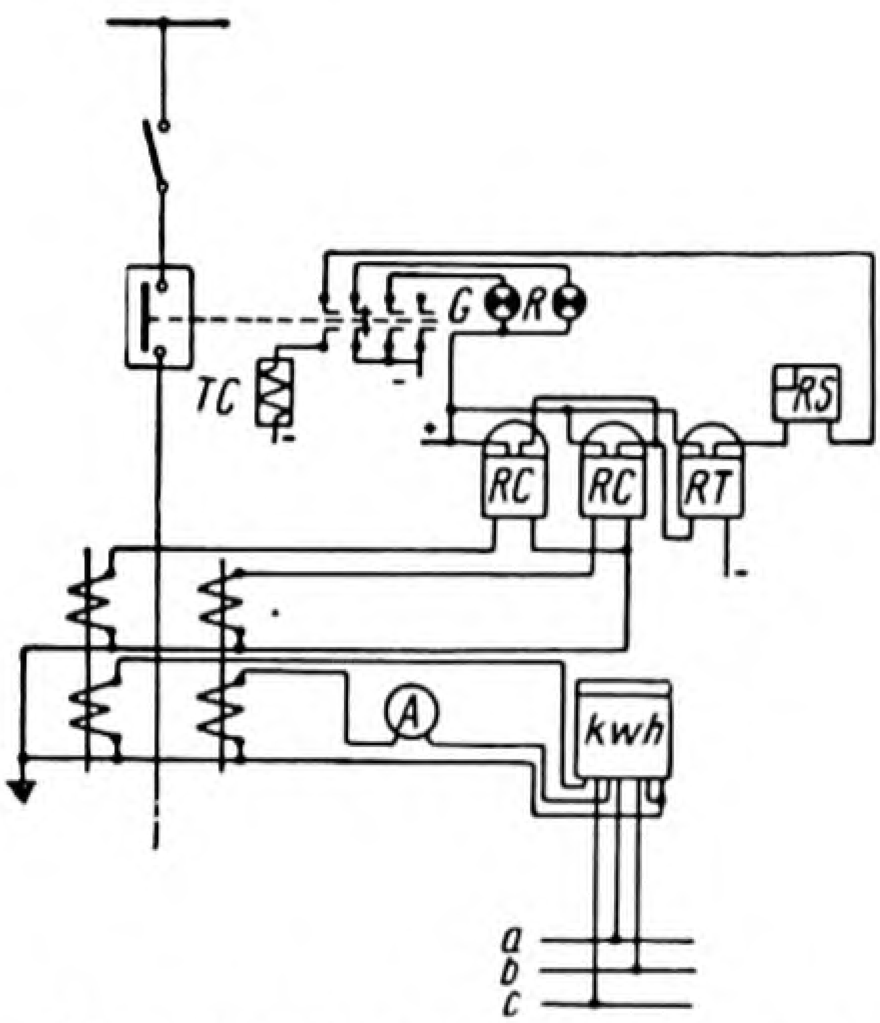


Fig. 29. Full schematic diagram of secondary or control connections

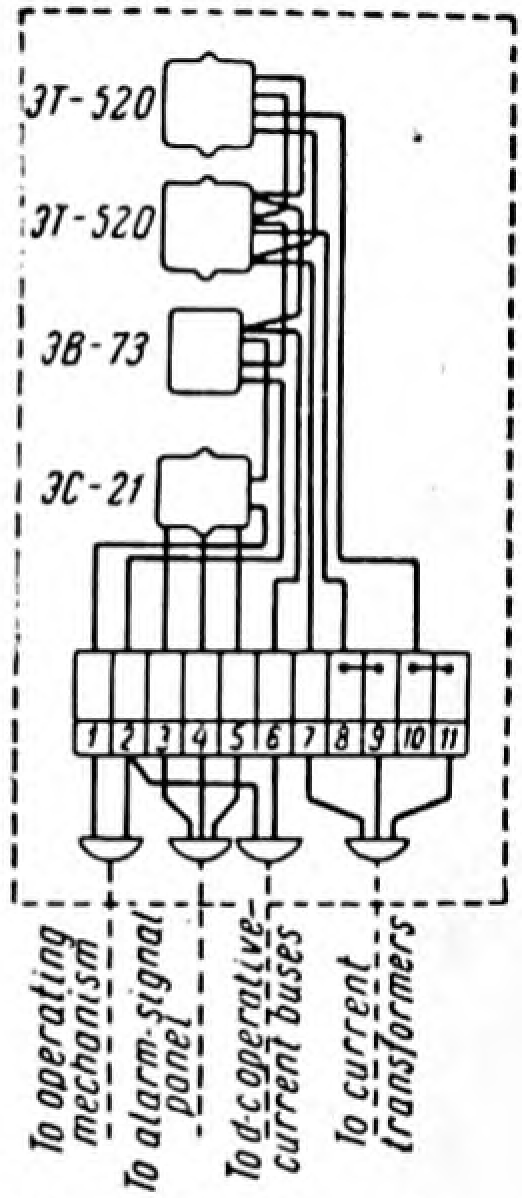


Fig. 30. Wiring diagram of a relay panel

devices associated with the bus system both during normal operation and under fault conditions. Full schematics are needed to make up wiring diagrams.

Wiring diagrams (Fig. 30) are working drawings which are used in installation work and also for trouble-shooting and maintenance. Wiring diagrams are drawn to scale and give the outline dimensions of the equipment to be installed. Wiring diagrams show all the small wiring, control cables, cable terminations and terminal blocks.

CHAPTER 3

INSTALLATION OF 6-10-KV INDOOR PRIMARY CIRCUIT EQUIPMENT

5. General

The equipment of primary circuits in indoor substations, as any other erection work, is carried out in a definite sequence which includes:

(1) marking-out of positions;

(2) placing of fastenings and supporting structures; laying of indoor and outdoor earthing circuits;

(3) setting up of support insulators;

(4) mounting of bushings and current transformers;

(5) mounting of busbars;

(6) mounting of isolators;

(7) mounting of circuit breakers;

(8) mounting of reactors;

(9) mounting of voltage transformers, high-voltage fuses, and arresters;

(10) installing of busbar tap-offs and of busbar connections between the apparatus;

(11) connection to the earthing system.

As a rule, the inner earthing circuit is laid concurrently with the placement of the fastenings and supporting metalwork and prior to mounting any of the apparatus, as the latter may suffer damage from spattered molten metal when the earthing busbars are welded in place.

The outdoor earthing circuit may be installed independently of the erection work inside the switchgear location and, indeed, at some other time. The actual sequence of erection work may vary from case to case. For example, the pieces of equipment put at the bottom of the sequence card may have to be set up earlier than those above only because the builders are behind schedule or the necessary equipment is not yet available, etc.

The sequence suggested above does not exclude the possibility of carrying out some of the operations in parallel. For instance, support insulators, bushings and current transformers may be set up concurrently. Again, circuit breakers and isolators may also be mounted at the same time, and so may the buses.

The practical way is to plan a schedule based upon the above sequence but tailored to the site conditions obtaining, taking into account the dates on which the builders will hand over the separate sections of the switchgear structures for erection work, the expected dates of equipment delivery, and availability of labour.

Prefabrication and shop assembly can appreciably reduce the erection time. Metal framework and fastenings should be ordered beforehand in specialised workshops. On the site, maximum use should be made of labour- and time-saving mechanisms and fixtures.

6. Marking-out of Positions

Marking-out is done to working drawings which specify the distances of the various items of electrical equipment from the floor, walls and ceiling, and also from one another.

In addition to faithfully transferring the distances given in the drawings, good marking-out must provide for a symmetrical arrangement of the equipment within the switchgear cells.

Using Fig. 31 as an example of a switchgear cell, we shall go through the process of position marking-out.

The first thing to do is to find the vertical axis (*A-B*) of the cell (Fig. 32). For this, a line *a-a'* is beat off at the top of the cell, with a string rubbed with dry chalk, charcoal, prussian blue, or ochre and the dimension *a-b* taken from the drawing is laid out on it in pencil to obtain point *A*. From this point a plum-bob is dropped, and the vertical axis *A-B* is beat off along it.

Then the horizontal centre lines *1-1*, *2-2*, *3-3*, *4-4* and *5-5* are laid out to the dimensions in the drawing, so that they are at right angles to the vertical axis *A-B*. This can be easily checked with a square or triangle as shown in Fig. 32.

The next step is to take the distances between the centres of the mounting holes from the actual equipment or drawings and to lay them off where the various pieces of equipment are to be installed.

Mounting holes can likewise be laid out with the aid of templates (Fig. 33), using the main axes of the cell and equipment to be mounted for reference.

On large modern substations and switchgear sites, the marking-out of positions for the equipment is done as part of the building work,

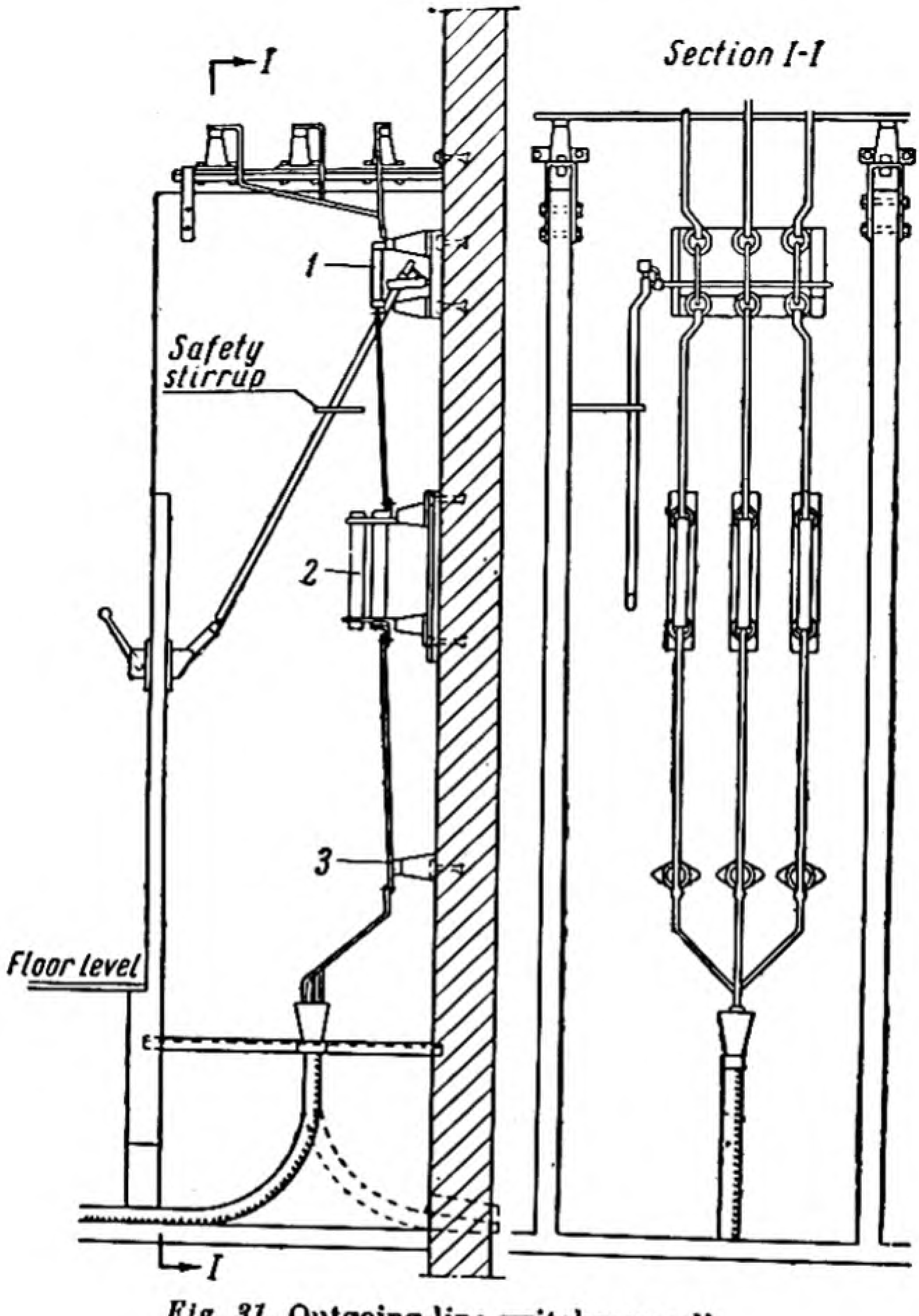


Fig. 31. Outgoing-line switchgear cell:
1—isolator; 2—fuses; 3—support insulators

as is provision of the necessary openings and mounting holes. This minimises waste of time and labour on hole-driving.

Advance layout is also practised when structures are assembled of precast concrete members. In this case the necessary insertion pieces are embedded in the concrete in the course of prefabrication, and the fastenings and metalwork are welded to them on the site.

In both cases the builders use special marking-out drawings based on the working drawings of the switchgear in question. However,

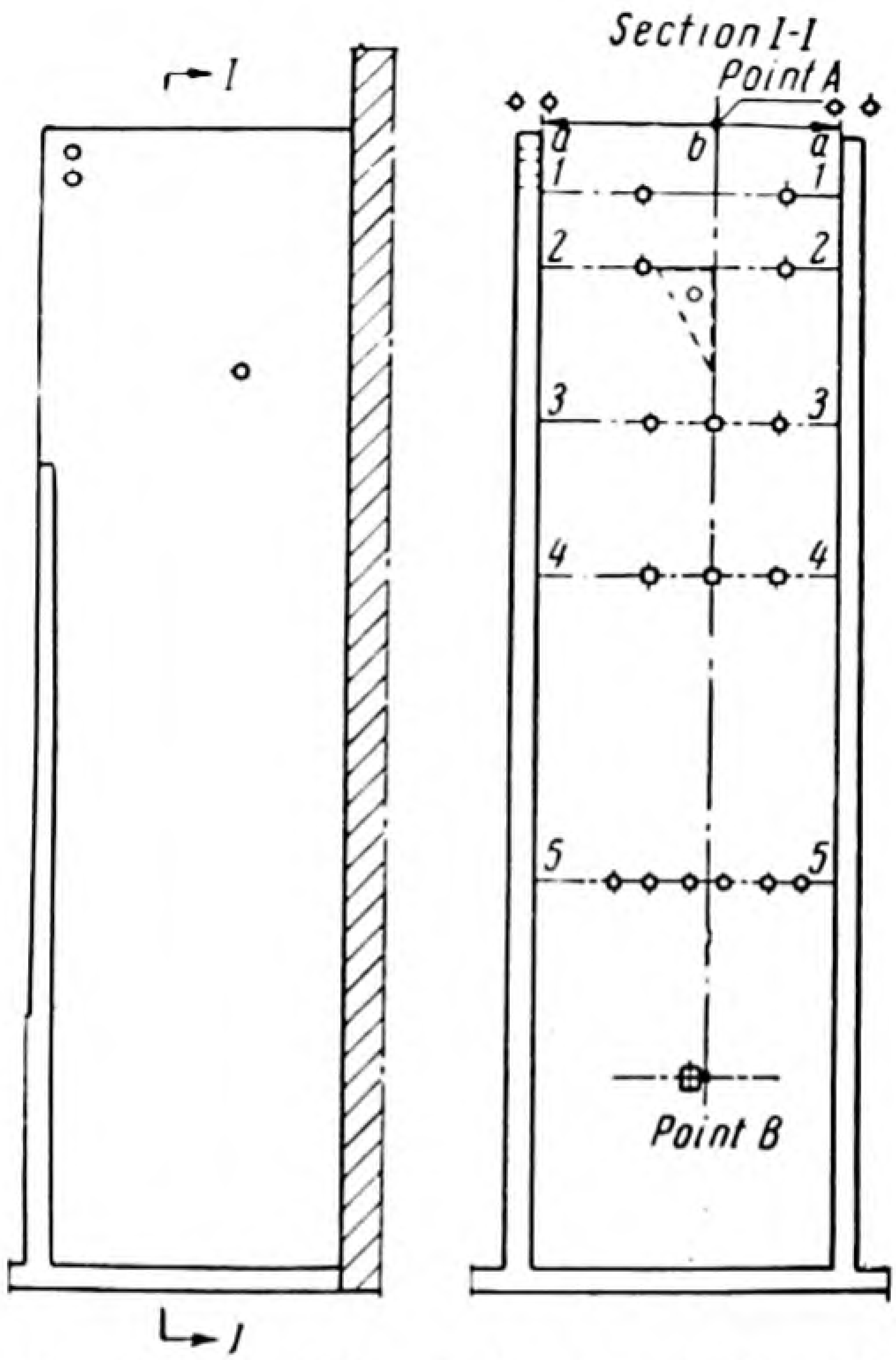


Fig. 32. **Layout drawing for outgoing-line cell**

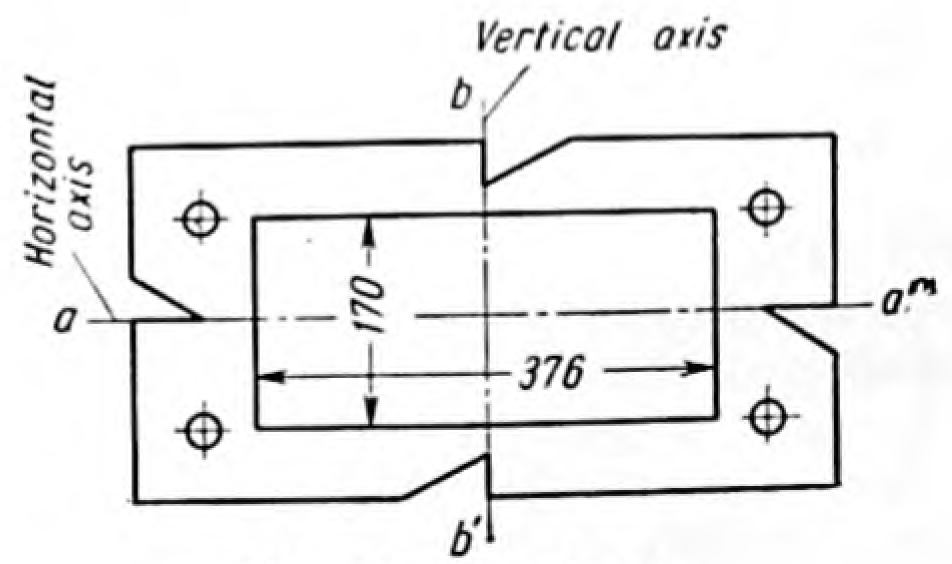


Fig. 33. Template:
a-a′ and b-b′—centre lines

holes are provided and insertion pieces are embedded with limited accuracy as to their relative position, and the electricians will have to check and correct the final positions.

A more recent trend has been to set up electrical equipment on steel channels (see Fig. 37) and angles embedded in concrete and on prefabricated metal frameworks (see Fig. 15) built into the structure in the process of building construction.

In this case the electricians have only to check the embedded metal parts and prefabricated metalwork for proper spacing against the respective working drawings.

Building contractors also prepare the positions for very heavy equipment, such as indoor minimum-oil, generator-voltage circuit breakers, reactors, and power transformers, for which they lay the foundations, leaving holes for the anchor bolts to be grouted in. The task facing the electricians is to check their dimensions against the working drawings.

7. Placement of Fastenings and Supporting Metalwork

The placement of fastenings and supporting metalwork begins with driving holes for them in the switchgear structure.

Where the equipment is to be fastened with anchor studs (Fig. 34*a*) or anchor bolts (Fig. 34*b*), or when support metalwork (Fig. 34*c*) requires grouting-in, blind holes will suffice.

Through holes are driven only where the equipment is to be fixed with studs (Fig. 34*d*) or through bolts (Fig. 34*e*).

Holes are driven with the aid of electric drills or air-operated tools. If the number of holes is quite small, they may, as an exception, be driven with a hammer and chisel.

Holes, both blind and through, must meet definite requirements which are generally specified in the working drawings.

The dimensions of mounting holes are governed by the following rules:

1. The diameter of blind holes should be 5 to 6 times stud or bolt diameter, their depth, 8 to 10 stud or bolt diameters for studs and bolts up to 15 mm in diameter, and 10 to 12 diameters for studs and bolts over 15 mm in diameter.

2. The diameter of through holes should be 2 to 2.5 times that of the bolts or studs.

3. The sides of holes for grouted-in support metalwork should be 1.5 to 2 times the size of the steel shapes from which the support is made; hole depth should range from 120 to 150 mm.

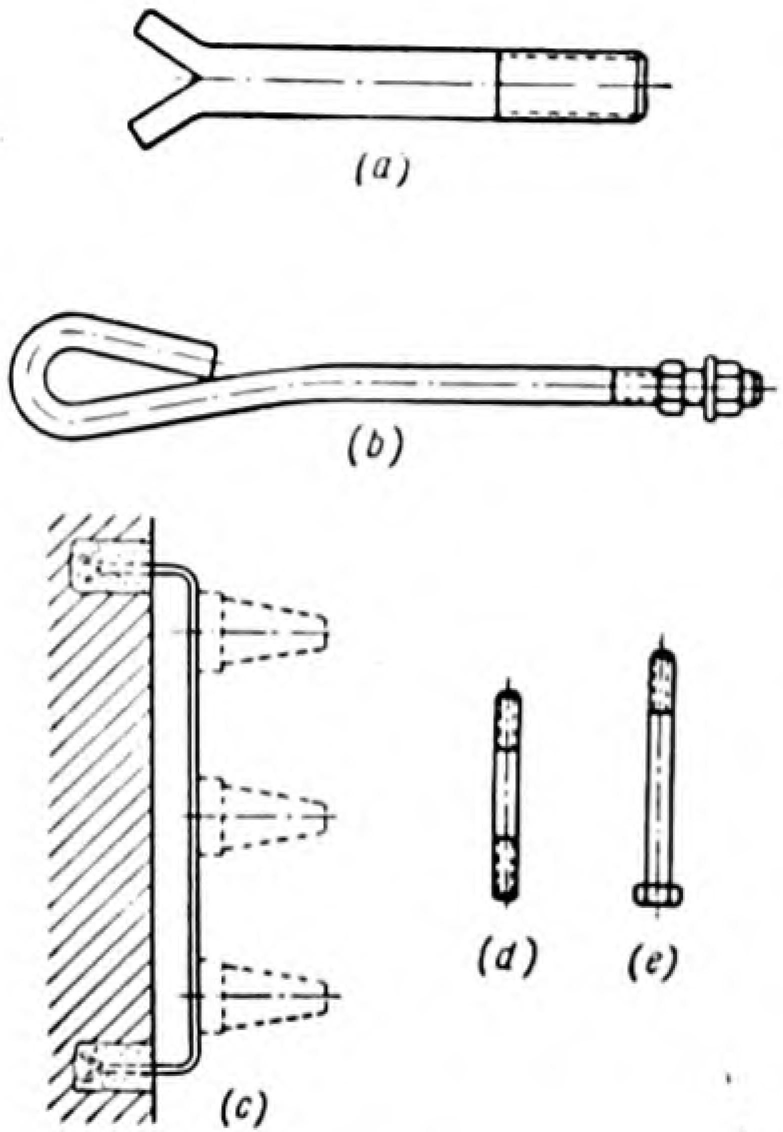


Fig. 34. Fastenings:
a—anchor stud; *b*—anchor bolt; *c*—grouted-in support metalwork; *d*—through stud; *e*—through bolt

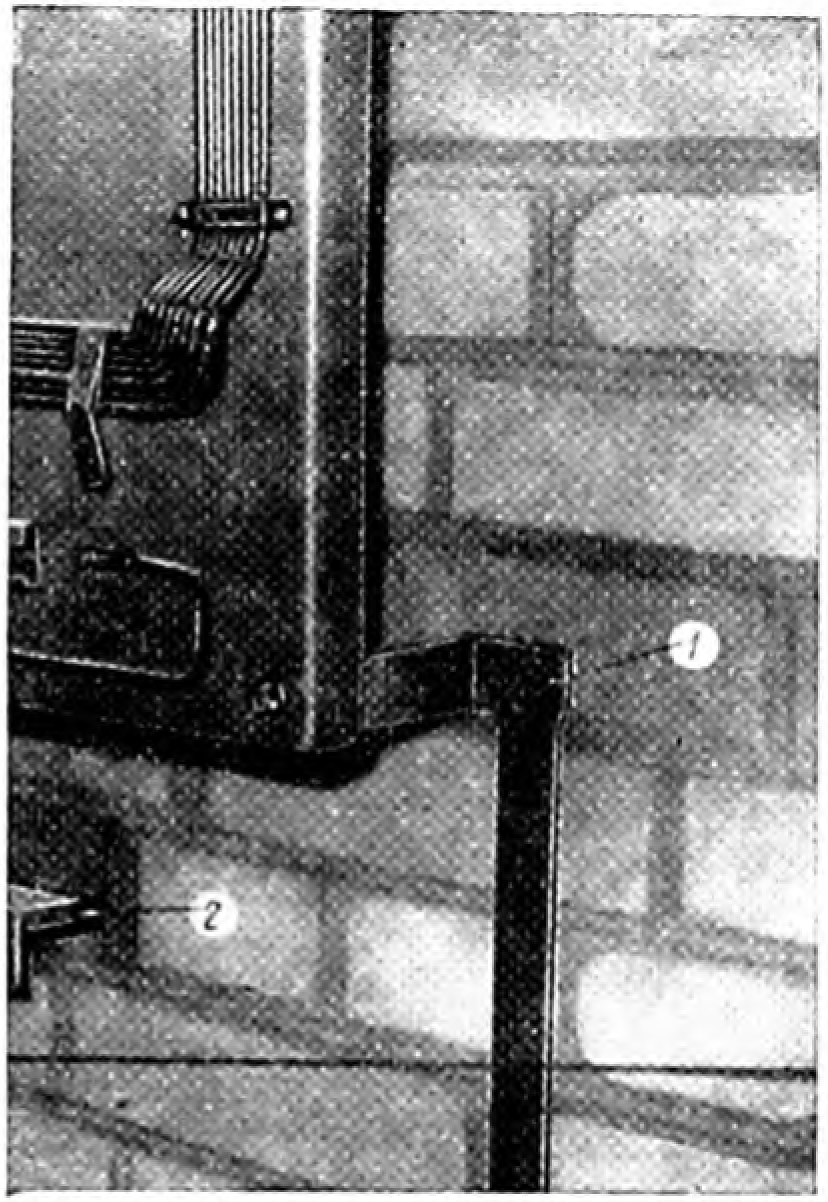


Fig. 35. Supporting parts and anchors fixed to wall with powder-actuated gun and welding:
1—relay board bracket (fastened with СМП dowel-driving gun; earthing strip welded); *2*—angle iron welded to dowels for control cables

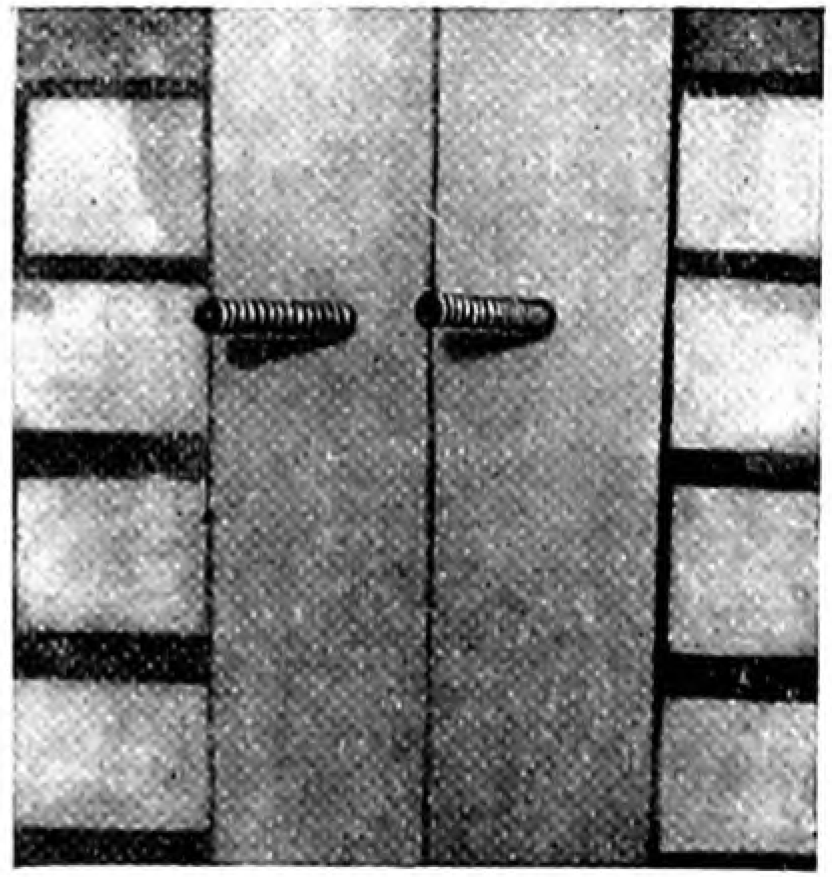


Fig. 36. Embedded studs

The grout used for this purpose should consist of one part of cement and 2 to 3 parts of sand. When grouting in support metalwork, one more part of fine-grained gravel or crushed brick is added to the grout.

Fastenings are grouted in as follows:

1. The hole is cleaned of crushed concrete or brick, dust, etc., and wetted with a swabbing brush.

2. The walls of the hole are given a coat of grout, then the hole is filled with grout, and the latter is thoroughly tamped in with a trowel.

3. A dowel, stud, bolt, or a foot of a supporting metalwork is hammered into the grout-filled hole; if the end of the part is threaded, it can be protected by placing a pad of softer material (wood) under the hammer or screwing on a nut.

4. As much as possible of the squeezed-out grout is worked back in with a trowel, excess grout is removed, and the face around the part is finished off flush with the surface.

5. The embedded parts are checked for proper positioning against the laid-out lines. Bolts and studs can be conveniently checked by means of laying-out templates, while metal supports are checked with a plumb-bob, and a level and straight edge.

A very efficient method of anchoring fastenings and supporting metalwork is with a powder-actuated gun which drives dowels or studs directly in concrete, steel and brick work. Examples of this technique as supplemented by welding, can be seen in Fig. 35.

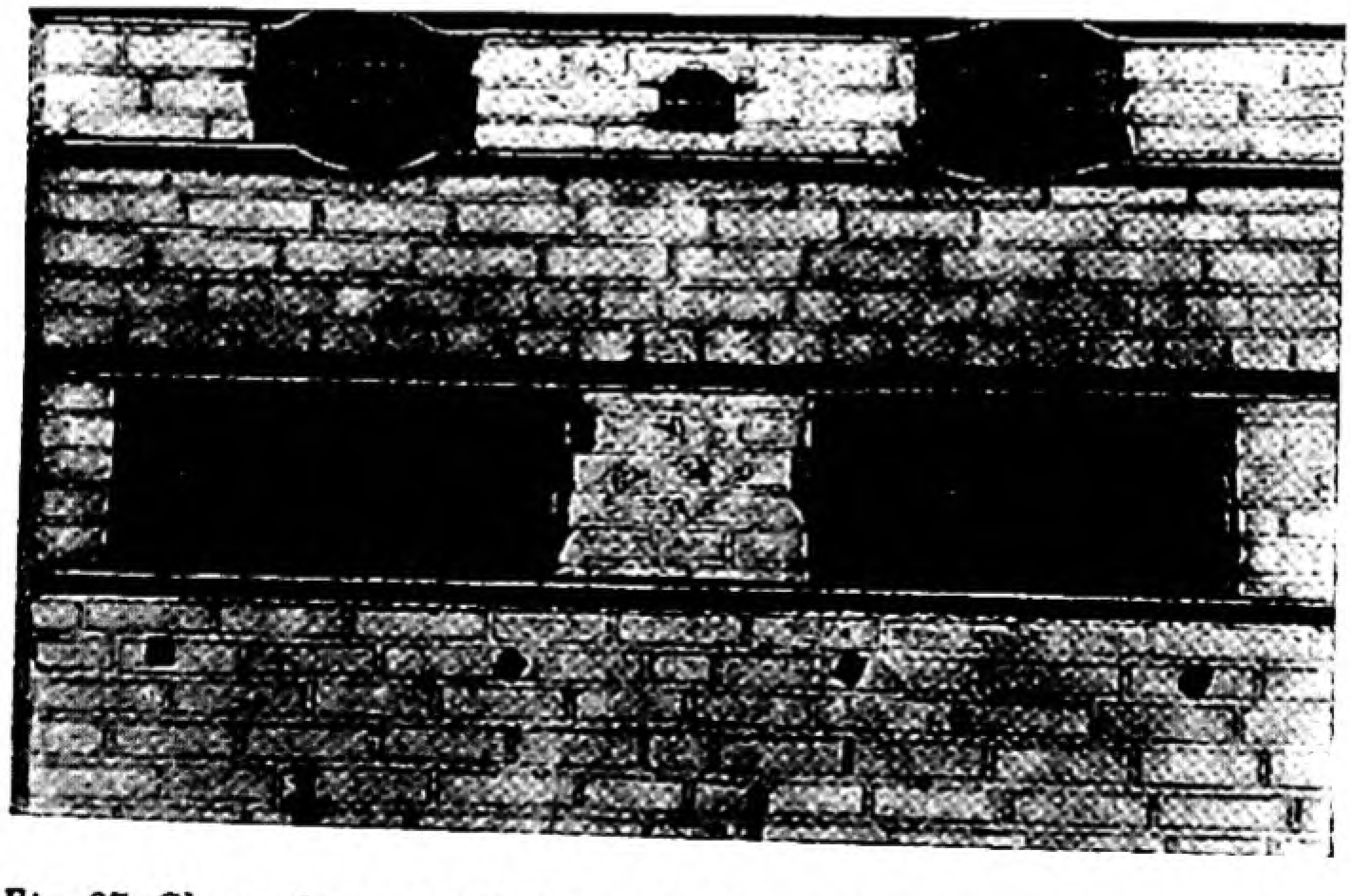


Fig. 37. Channels embedded in wall for mounting current transformers and a bushing in switchgear room

In the case of prefabricated concrete structural elements, the necessary mounting holes are provided at the manufacturer's works.

Another practice is to embed steel pieces and studs (Fig. 36) into in-situ poured concrete, and weld metal supports to the steel pieces or fasten them on the studs with nuts. Fig. 37 shows channels embedded in a brick wall for mounting current transformers and a bushing.

8. Mounting of Support (Post) Insulators

Support insulators serve to fasten and insulate current-carrying parts from earth and other elements which are at a different potential.

Indoor switchgear uses indoor-type support insulators (Fig. 38). The standard types used in the Soviet Union are summarised in Table 4 which lists their principal dimensions and weights, while

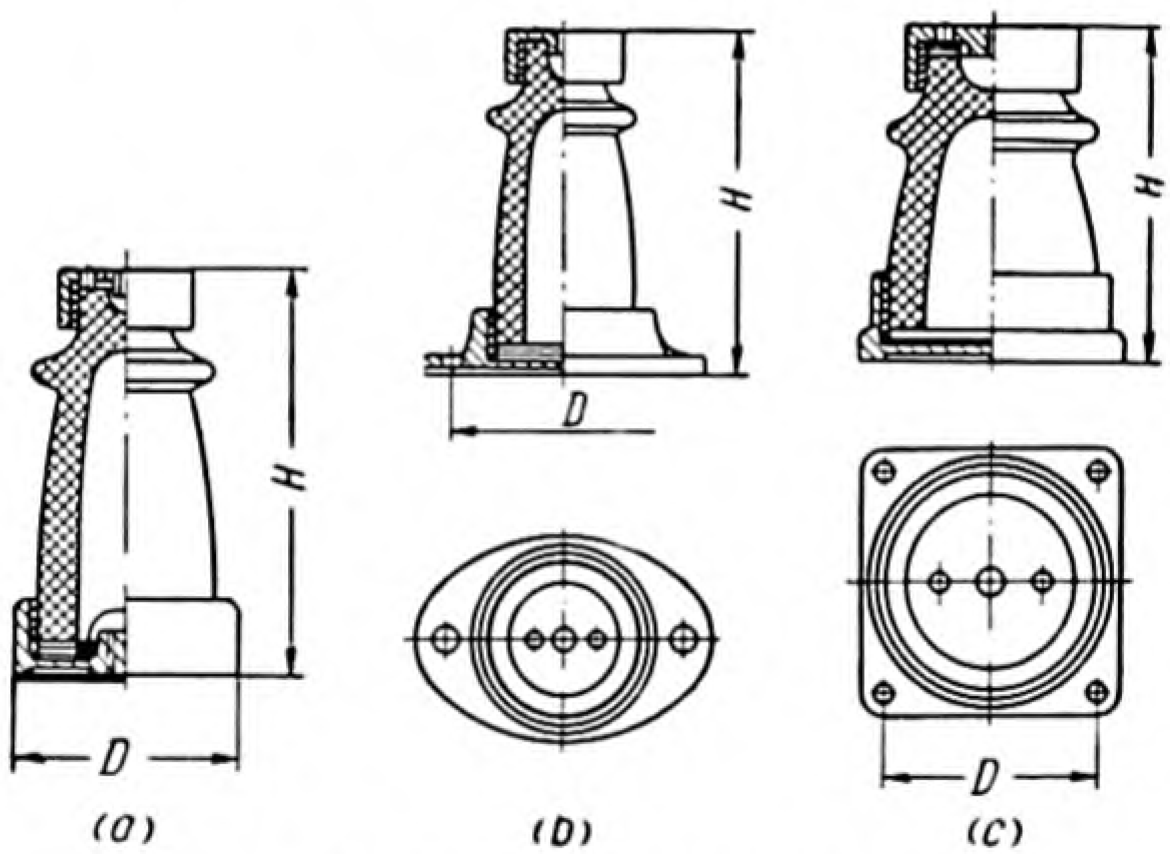


Fig. 38. Support (post) insulators:
a—with round base fitting; b—with oval base fitting; c—with square base fitting

Figs 39 and 40 show different classes of support insulators grouped by voltage ratings, mechanical strength, and form of base fitting.

Support insulators must comply with the following requirements:

(a) the porcelain must have no chipped spots, metallic inclusions, unglazed spots or haircracks in the glazing;

(b) the cap and base fittings should be securely cemented on;

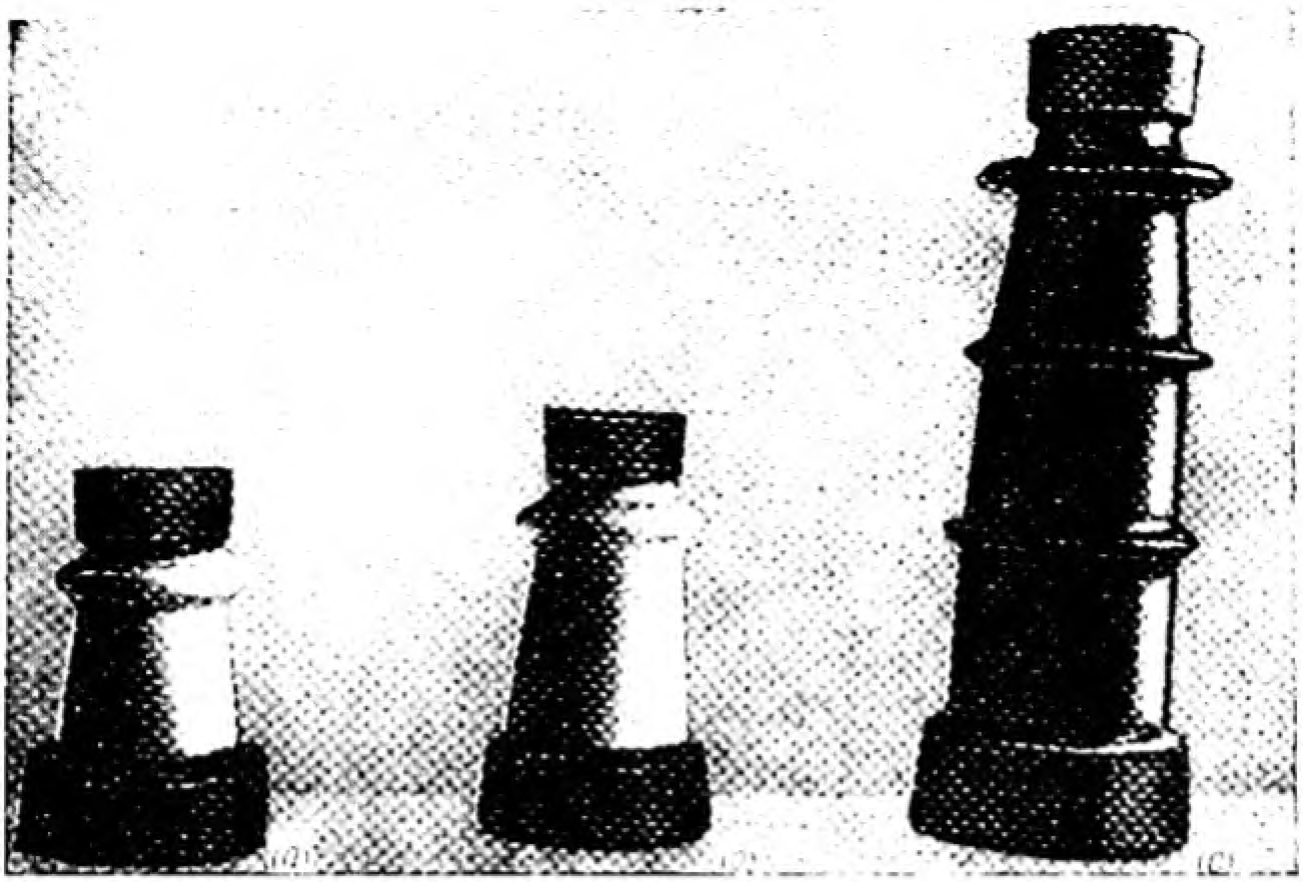


Fig. 39. Support insulators:
a—6 kv; *b*—10 kv; *c*—35 kv

(c) the tolerance on lack of parallelism between the cap and the base-fitting plane is 1 mm (see Fig. 41*a*); this tolerance also applies to the offset of the cap or base fitting from the centre line of the insulator (Fig. 41*b*);

(d) insulators should not differ in height by more than ± 2 mm. Insulators having the same deviation should be used within one cell or on one section of busbars.

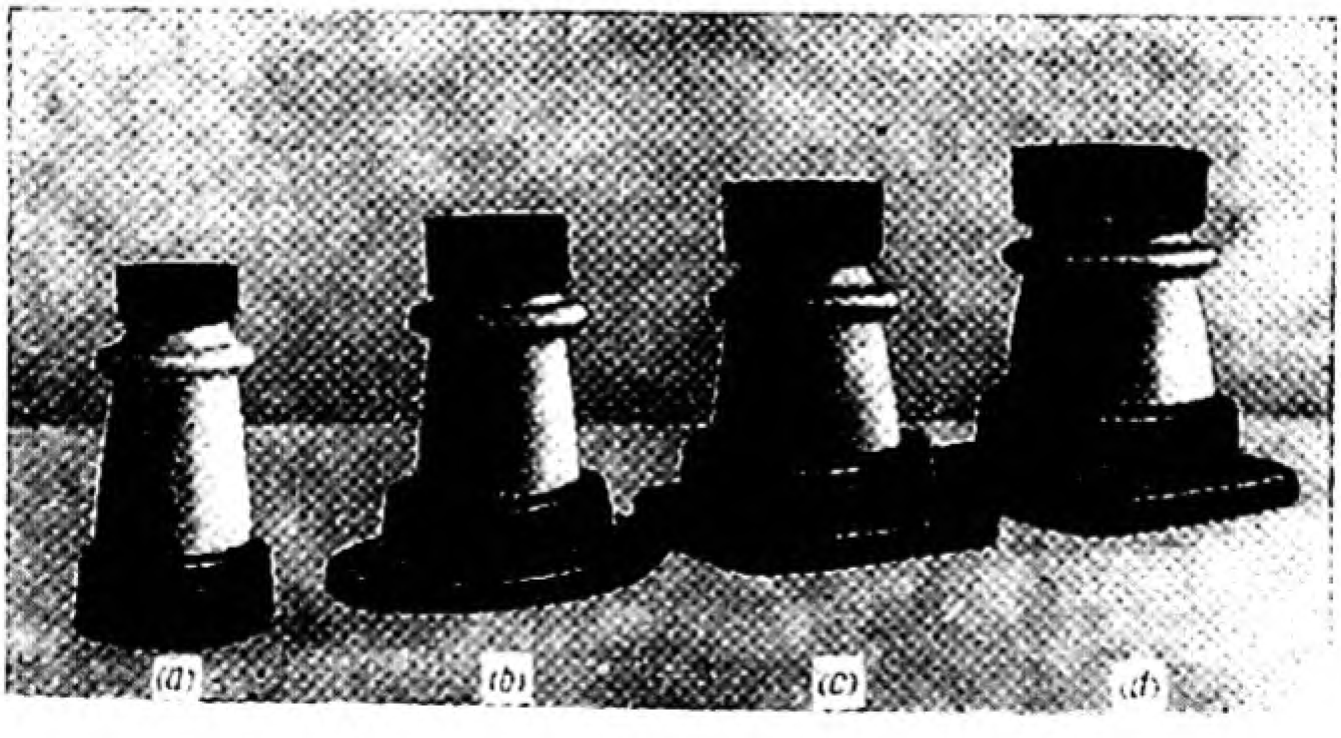


Fig. 40. 10-kv support insulators of different mechanical strength rating and form of base fitting:
a—OA-10-kp insulator; *b*—OБ-10-ов insulator; *c*—OB-10-кв insulator; *d*—OД-10-кв insulator

Table 4

Types, Principal Dimensions and Weights of 6-kv and 10-kv Support Insulators for Indoor Use

Type designation	Principal dimensions (see Fig. 38), mm			Weight per insulator, kg (appr.)
	H	*D*	d_1^*	
ОА-6-кр	165	108	M12	2.4
ОА-6-ов	165	135	2×12	2.6
ОА-10-кр	190	108	M12	2.5
ОА-10-ов	190	135	2×12	2.9
ОБ-6-кр	185	132	M16	4.2
ОБ-6-ов	185	175	2×15	4.9
ОБ-10-кр	215	132	M16	4.6
ОБ-10-ов	215	175	2×15	5.5
ОВ-10-кв	120	150	2×15	6.4
ОД-10-кв	235	155	4×15	7.6

* d_1 — diameter of bolt hole or threaded hole size.
Note: The letters in the type of designations stand as follows: O for "support insulator", А, Б, В, Д, for mechanical strength rating, ов, for "oval flange", кр, for "round flange", and кв, for "square flange".

The sequence of installation for support insulators includes:
(1) marking out of positions;
(2) placement of fastenings and supports;

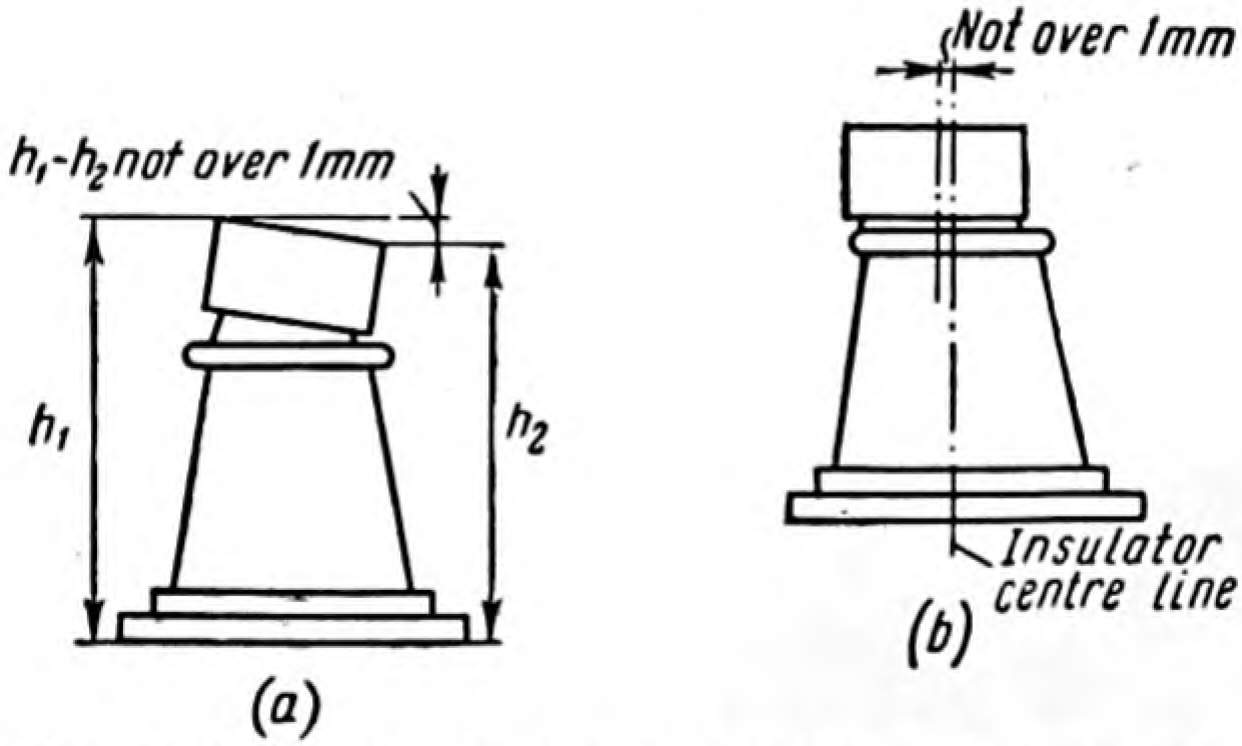


Fig. 41. Tolerances on lack of parallelism between cap and base, and on offset of cap or base from insulator axis

(3) mounting of insulators;
(4) aligning and fixing of the insulators;
(5) connecting to earthing buses.

An example of marking out holes for support insulators is given in Fig. 32.

Fastenings for support insulators may be anchor studs, through studs or bolts. Anchor studs are mainly used on brickwork (Fig. 42*a*); through studs and bolts, on concrete structural elements (Fig. 42*b*).

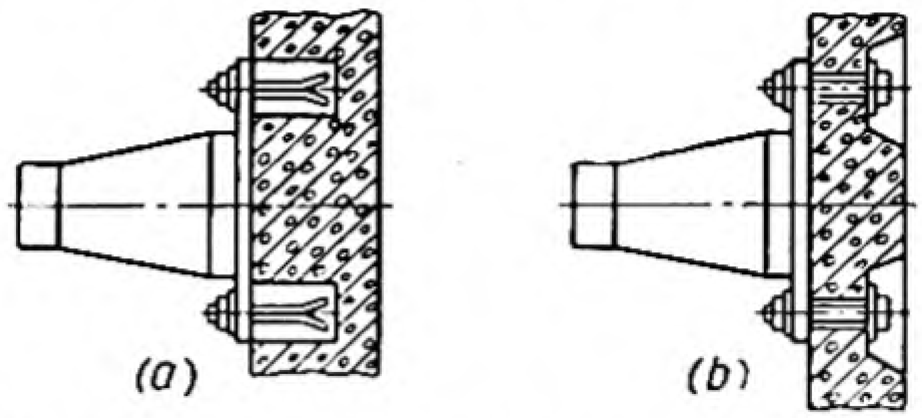


Fig. 42. Support insulators mounted on walls:
a—with anchor studs on masonry wall; *b*—with through bolts on concrete wall

Supports for insulators are made from steel angles and strip and held in place by anchor studs, through studs, or bolts (Fig. 43), or are embedded in walls.

In mounting, aligning and finally securing support insulators, care must be taken that the caps and bases deviate from the longitudinal and transverse axes only within ±1 mm.

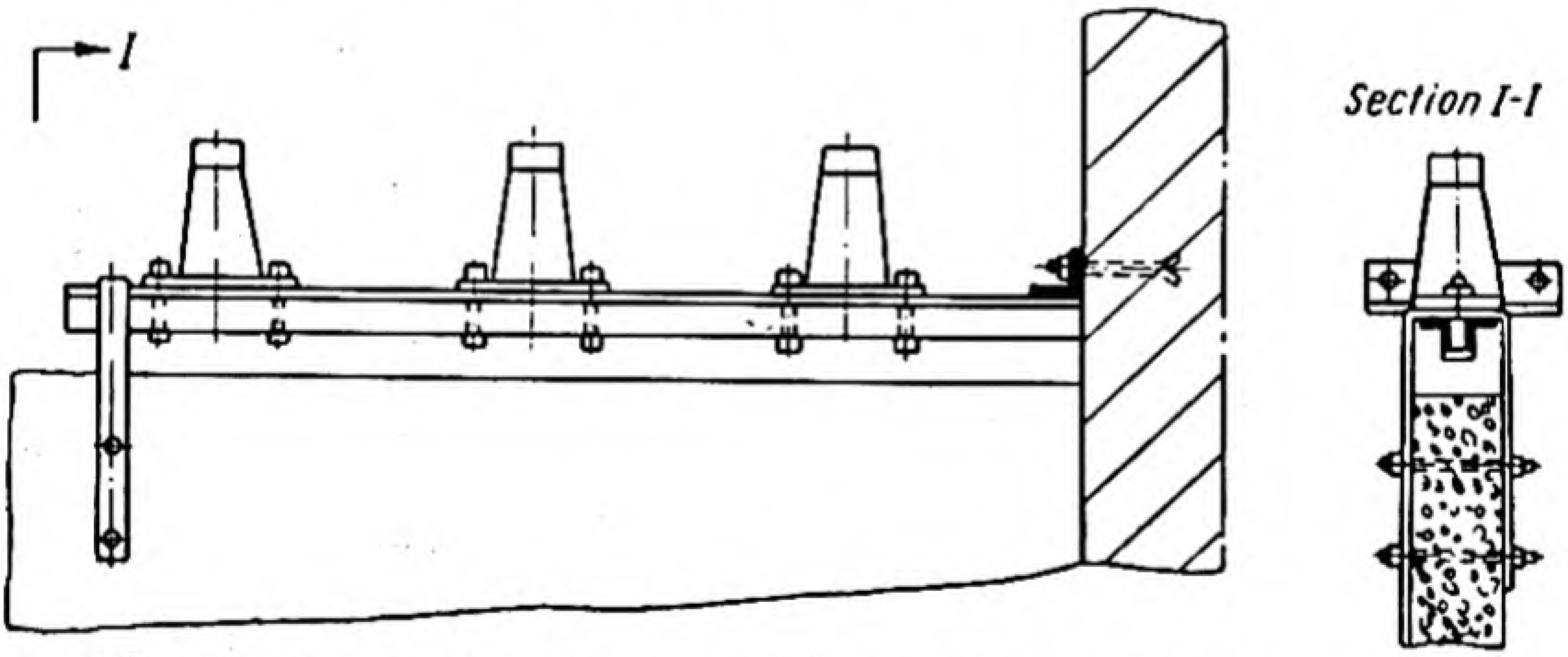


Fig. 43. Support insulators mounted on steel angle frame support

The caps of the insulators in any one group, and also in one cell or on a given bus section should be within ±2 mm of the same level. Their alignment is checked with a spirit level and a straight edge (Fig. 44). Misalignment is remedied by inserting steel shims under the insulator bases, or by slipping steel washers on the fixing bolts.

The centre distance between the phases (dimension "a" in Fig. 44) and the distance of the outer-phase centre line to a structural surface or earthed member (dimension "b") must be within ± 2 mm of the dimension given in the working drawing. This tolerance also applies to the insulators of any one phase (along the centre line of the phase).

Support insulators are set up on supporting metalwork and the top edges of partitions in the switchgear structure concurrently with marking-out. Using a folding steel rule, the positions of the outermost insulators at both sides are laid out and then the insulators

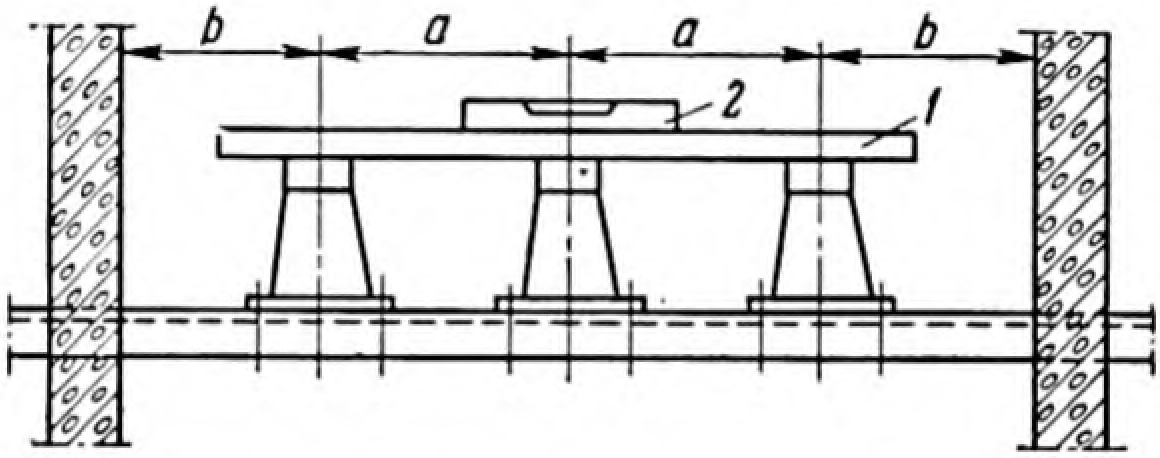


Fig. 44. Support insulator alignment being checked with level and straight edge:
a—straight edge; b—spirit level

are installed. Next a string, thin flexible cable or steel wire is strung between two opposite end insulators and the intermediate insulators are set up in line with them.

Support insulators mounted on brickwork or concrete are earthed by means of bolts provided on their bases. The insulators should be so mounted that these bolts and, therefore, the earthing busbar strips are on one and the same side.

For reliable electric contact, the mating surfaces of the earthing busbar and bolt are cleaned until bright and then given a thin coat of petroleum jelly or neutral grease to protect against corrosion.

Where insulators are mounted on metalwork, the individual insulator bases need not be earthed, as the entire metalwork is earthed. In such instances the bottom surface of the bases and the mounting seats on the metalwork are cleaned until bright and likewise coated with petroleum jelly or neutral grease.

Example. Write up a sequence card for mounting ОА-6-кр support insulators and the associated metalwork as shown in Fig. 43. Assume that the holes in the brickwork and concrete have been provided by builders.

The form for such a card is given in Sec. 1, and it is filled in as shown in Table 5.

Table 5

Mounting Sequence Card
for Support Insulators and Supporting Metalwork Shown in Fig. 43

No.	Operation	Tools	Materials	Procedure
1	Grout-in anchor studs in ready holes	Mixing bowl, trowel, hammer swabbing brush	Portland cement and sand in 1:2 proportion, M16 anchor studs complete with nuts and washers	First wetten ready hole; screw on nuts to avoid damage to thread on studs when hammering them in. Work back squeezed-out grout as much as possible and smoothen surface around studs with trowel
2	Set and secure metalwork in place with anchor or through studs	Spanner for M16 nut, adjustable wrench, hammer, level, folding rule	M16 through studs complete with nuts and washers	Wait for grout to set and start mounting metalwork. Carefully level metalwork
3	Mount insulators on supporting metalwork	Bastard file, spanners for M12 and M16 nuts, adjustable wrench, hammer, wooden straight edge, level, folding rule	M12 bolts complete with nuts and washers; petroleum jelly or neutral grease, steel shims or split washers	Before mounting insulators, clean bases and their mounting seats on metalwork with a bastard file, then coat with rust preventive. Level insulators with straight edge and spirit level. Make sure that their centre-to-centre distances comply with working drawing

Note: When the support metalwork must be mounted right after studs have been embedded, add one litre of water glass per bucket of grout.

Another method of mounting is to first mount insulators on a metalwork and then fix the entire assembly in place.

Problem. Using the above example for guidance, write up a sequence card for mounting three ОА-6-кр support insulators on brickwork with the aid of a bracket, as shown in Fig. 34c. Include in the card the marking out of positions for the bracket and hole-driving.

9. Mounting of Bushings

Bushings (Fig. 45) serve to carry live parts through walls and floors in switchgear structures.

Some of the standard types of indoor bushings used in the Soviet Union, including their main dimensions and weight are given in Table 6.

Table 6

Types, Main Dimensions and Weight of Several Indoor Bushings

Type designation	Dimensions, mm		Weight, kg	Remarks
	A	B		
ПА-6/400	375	132	3.5	Dimensions according to Fig. 45*a*
ПА-6/600	406	132	4.5	as above
ПБ-10/600	425	165	6.6	dimensions according to Fig. 45*b*
ПБ-10/1000	625	175	13	as above
ПБ-10/1500	625	175	15.2	as above
ПВ-6/1000	580	155	17.5	as above
ПВ-10/1000	640	155	18.5	as above
ИПШ-I-10	560	200	15.5	dimensions according to Fig. 45*b* and Fig. 46*b*
ИПШ-II-10	560	230	21.5	as above
ИПШ-III-10	560	260	29	as above

In the type designation of these insulators the letter П stands for "bushing"; the letters А, Б, В, the mechanical strength rating; the letter И, "insulator"; and the letter Ш, "bus or window" type. The numerator denotes the kilovolt rating, and the denominator, the current rating. The Roman figures I, II and III indicate the mechanical strength rating for ИПШ bus-type bushings (Fig. 46).

In bushings, the porcelain and cemented metal fittings must meet the same requirements as their counterparts in support insulators do. Bushings with built-in conductors are also checked to see that the conductors are snugly held in place and their threads are not damaged.

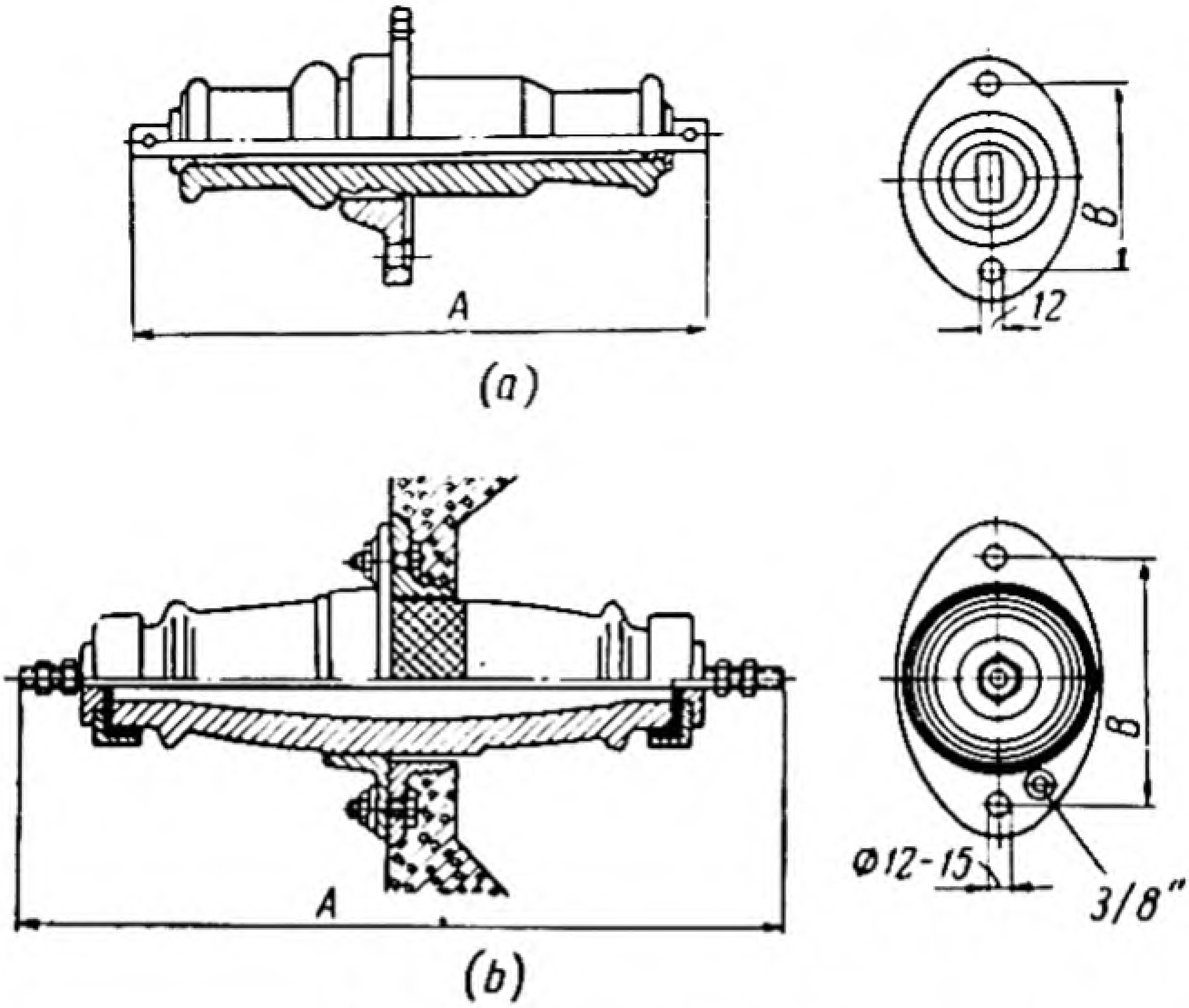


Fig. 45. Indoor bushings:
a—ПА bushing for 6-10 kv, 200 to 600 a; *b*—ПБ bushing for 6-10 kv, 1,500 a.

A typical sequence of operations for mounting bushings will include:

(1) marking out of positions for supporting components;

(2) mounting of supporting components;

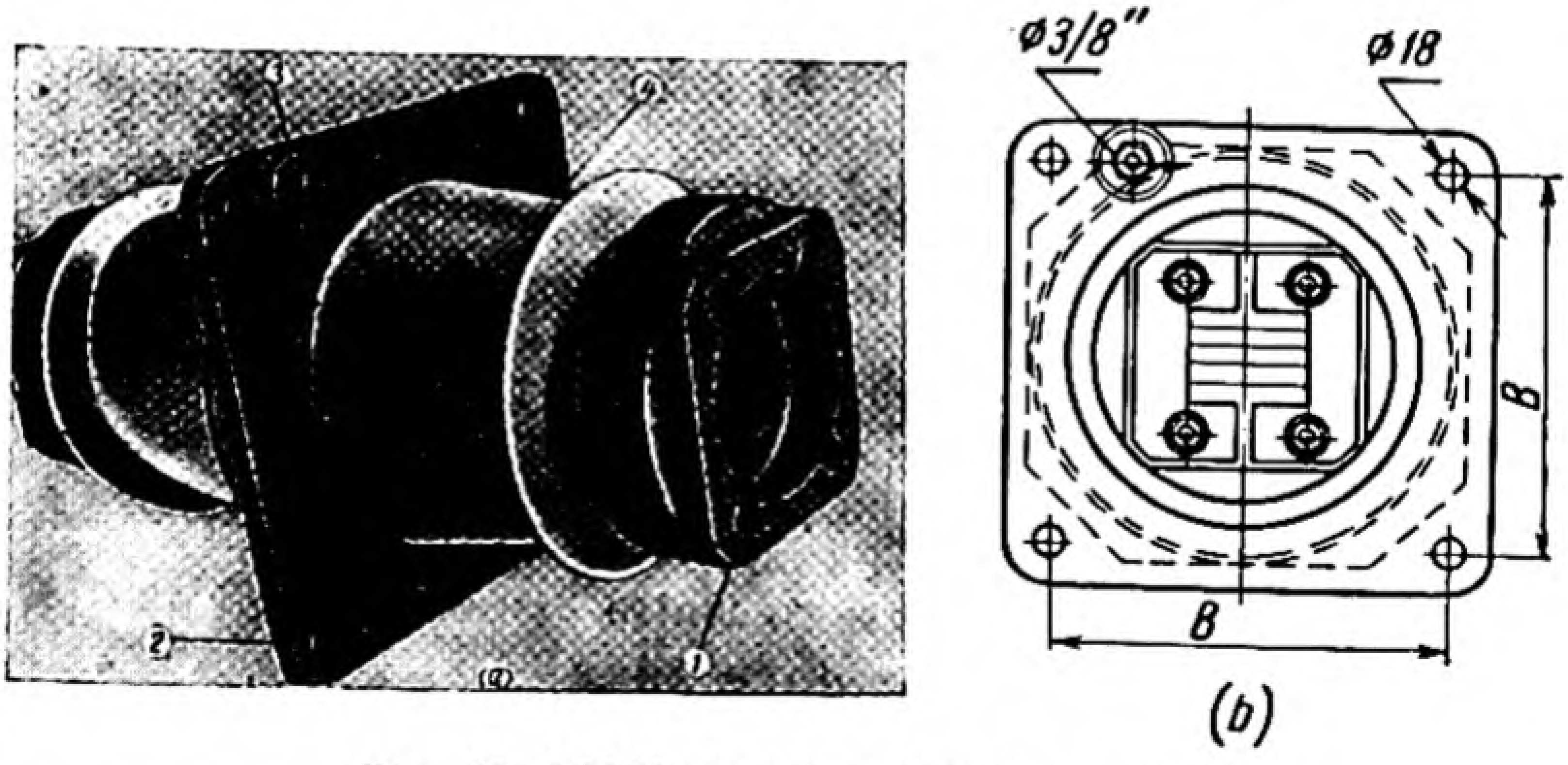


Fig 46. ИПШ-II-10 bus (window) type bushing:
a—general view; *1*—cap; *2*—flange; *3*—earthing bolt; *4*—porcelain body; *b*—view of insulator flange

(3) setting up, alignment, levelling and fixing of the bushings;
(4) connection to an earthing bus.

Bushings are usually mounted on ferro-concrete or steel slabs in openings provided in floors and walls (Fig. 47*a*), or on supports from steel strip or angles (Fig. 47*b*).

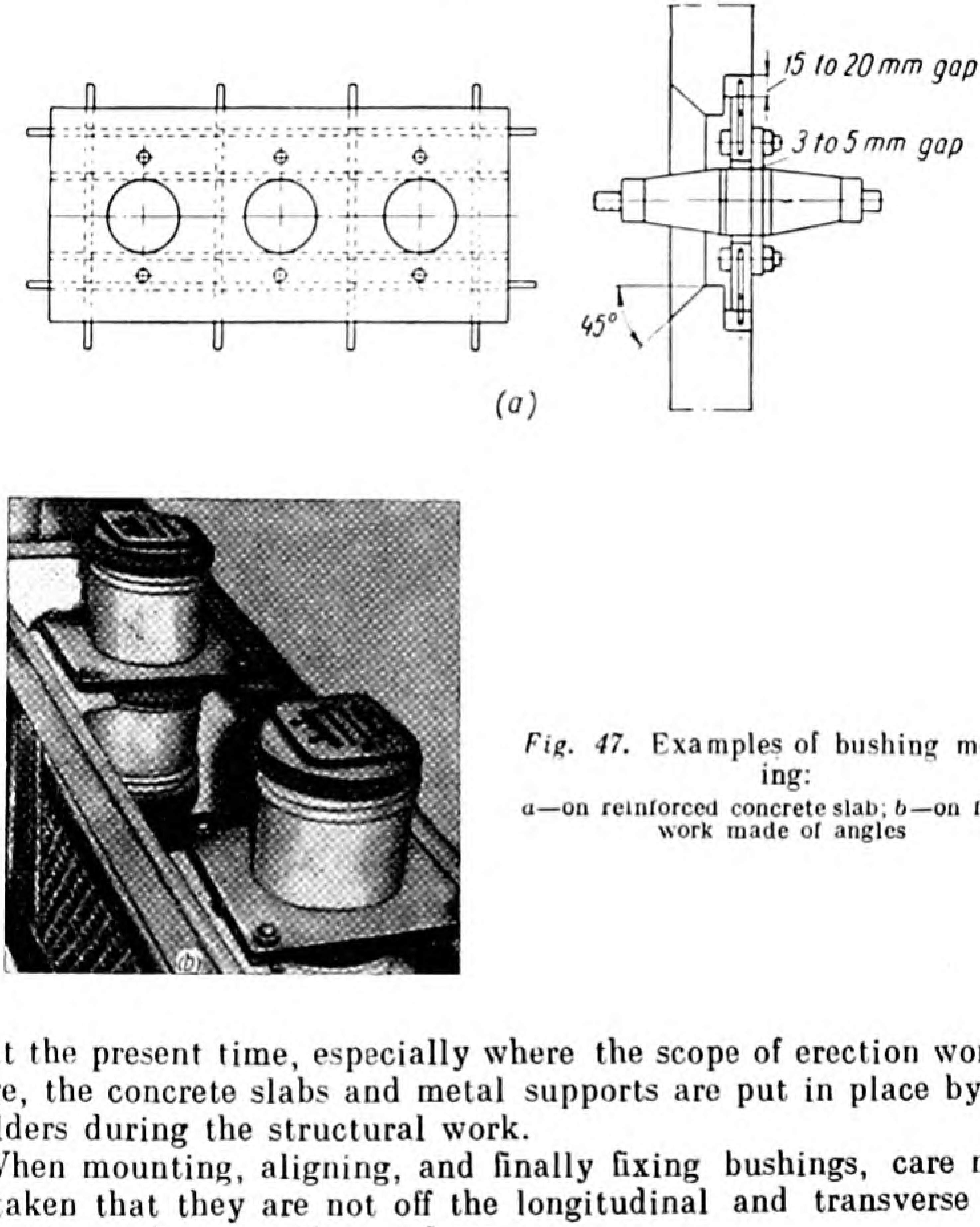


Fig. 47. Examples of bushing mounting:
a—on reinforced concrete slab; *b*—on framework made of angles

At the present time, especially where the scope of erection work is large, the concrete slabs and metal supports are put in place by the builders during the structural work.

When mounting, aligning, and finally fixing bushings, care must be taken that they are not off the longitudinal and transverse laying-out axes by more than ± 2 mm.

The tolerance on the centre-to-centre distance is ± 3 mm for the dimension specified in the working drawing.

The longer end of a bushing should be on the chamfered side of the opening (see Fig. 47*a*), which should face away from the control aisle when the bushings are mounted horizontally and point downward when the bushings are mounted vertically.

Bushings are aligned and levelled by means of a plumb-bob, straight edge and spirit level, a folding rule and a scale. Misalignment is remedied by means of split washers or steel shims.

The flanges of bushings must be earthed as are support insulators.

Problem. Write up a sequence card (use the form given in Sec. 1) for mounting window-type ИПШ-II-10 bushings on a framework from steel angles (see Fig. 46*b*). The framework was grouted in by the builders.

10. Mounting of Isolators (Disconnecting Switches)

One of the most important measures which ensure safety to personnel working on high-voltage equipment in substations is to isolate it from live buses or apparatus, by providing a visible break in the circuit. This function is performed by isolators or disconnecting switches.

Isolators or disconnecting switches have no arc-control devices. Because of this, they may only be operated on dead circuits first opened by the associated circuit breaker, or on energized circuits with small charging and no-load currents, when and if so specified.

Indoor isolators or disconnecting switches are generally available in single-pole and three-pole designs (Fig. 48).

Some of the types used in the Soviet Union and their dimensions and weight are listed in Table 7.

Table 7

Types, Installation Dimensions and Weight of Several Types of Isolators

Type designation	Installation dimensions, mm (Fig. 48)		Weight, kg
	A	B	
PBO-6/400	—	480	7.0
PBO-6/600	—	480	7.5
PЛBO-10/1000	—	442	20
PЛB-III-10/1000	830	346	75
PBT-10/1000	965	406	88
PBK-10/4000	270 *	455	200

* Dimension for one pole.

The letters and numerals in the type designations stand for: the letter P for "isolator"; B, "indoor"; O, "single-pole"; T (or III), "three-pole"; Л, "line-current circuit"; K, "square blade"; the figures

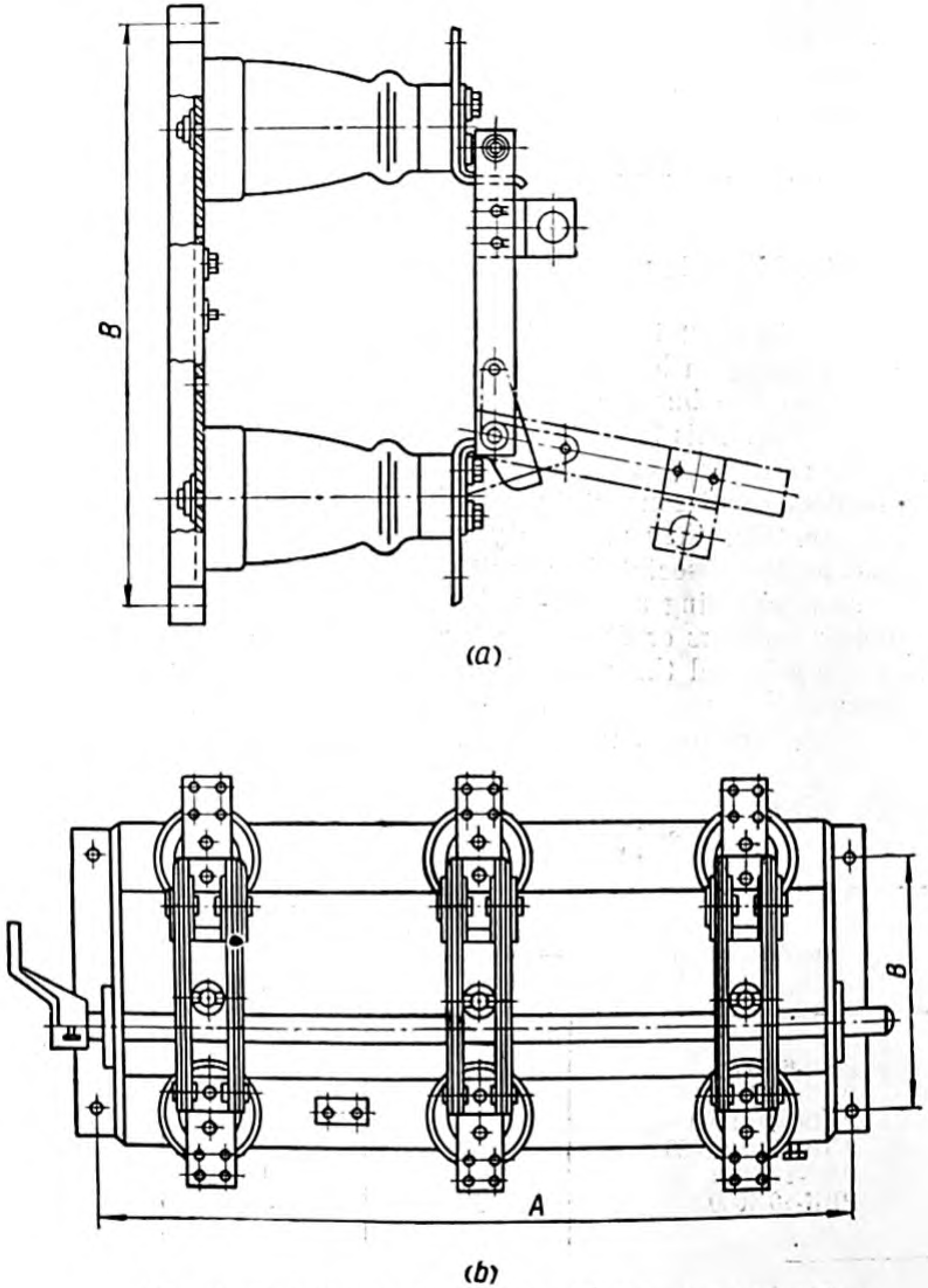


Fig. 48. Installation dimensions of indoor isolators:
a—single-pole; *b*—three-pole

in the numerator for the kv rating, and the figures in the denominator, for the current rating.

A general view of a three-pole isolator can be seen in Fig. 49.

Before they may be mounted, isolators should be thoroughly inspected. The contact surfaces should not be pitted, oxidised, or bent. The blades should enter the fixed contacts smoothly and without bumping. Otherwise, it may be necessary to either shift the insulators of the fixed contact or place steel shims under them.

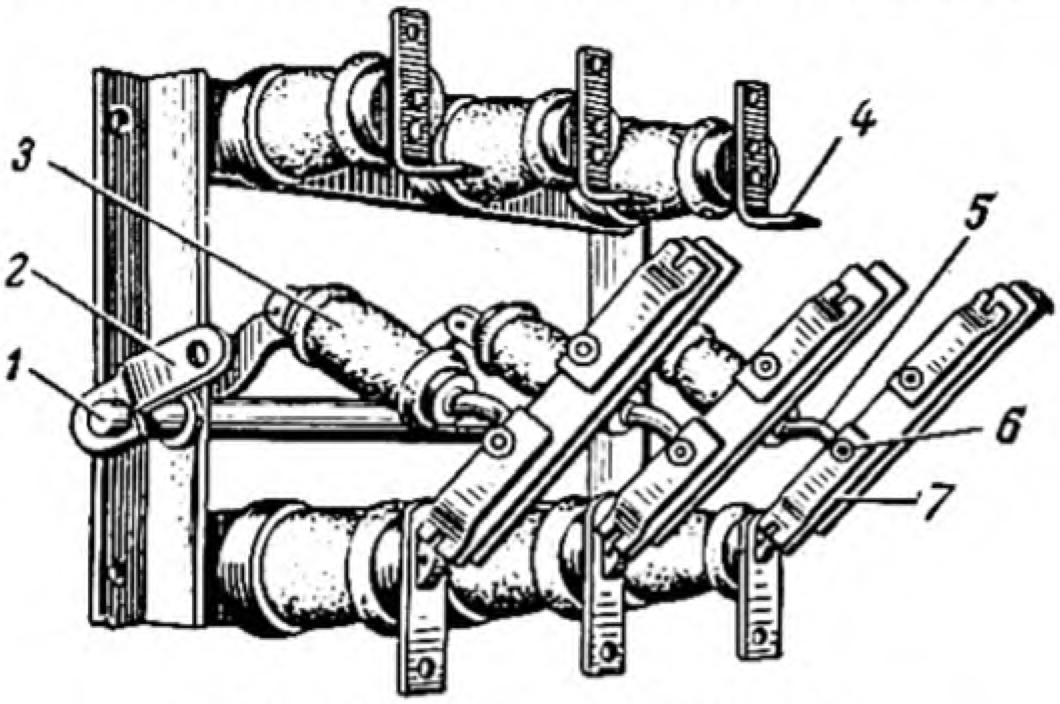


Fig. 49. Three-pole isolator:

1—shaft; 2—shaft actuating lever; 3—rocking porcelain tie rods; 4—fixed contacts; 5— force links; 6—magnetic latches; 7—moving contact blades

The blades should be able to move through the angles specified by the manufacturer. These angles for some of the isolators are given in Table 8.

Table 8

Angles of Rotation for the Blades of Several Types of Isolators

Type of isolator	Angle when fully open, deg.		
	operating handle	blades	shaft
PBO; 6-10 kv; 400 to 2,000 a	—	90	—
PBT; 6-10 kv; 400 to 500 a	150	65	90
PBT; 6-10 kv; 1,000 to 1,500 a	150	65	90
PB; 10 kv; 600 a	150	65	60
PBK; 10 kv; 2,000 to 6,000 a	180	75	115

The angle of rotation can be adjusted by altering the length of the link *5* of the rocking porcelain insulators *3* (see Fig. 49), or by adjusting

the length of the tie rod between the isolator and its operating mechanism (see Fig. 54).

Concurrently with adjusting the angle of blade rotation, the three contacts are checked to see that they close simultaneously. In isolators for up to 10 kv, the difference between the blades on closing must not exceed 3 mm. This means that when the blades of one phase just touch their fixed contacts, the blades in the other two phases must be not more than 3 mm away from their fixed contacts.

Next checked is the contact pressure. It is judged by the force required to pull a blade from its fixed contact. The force is measured with a spring dynamometer and should be 0.3 to 0.4 of the normal pressure between the contacts.

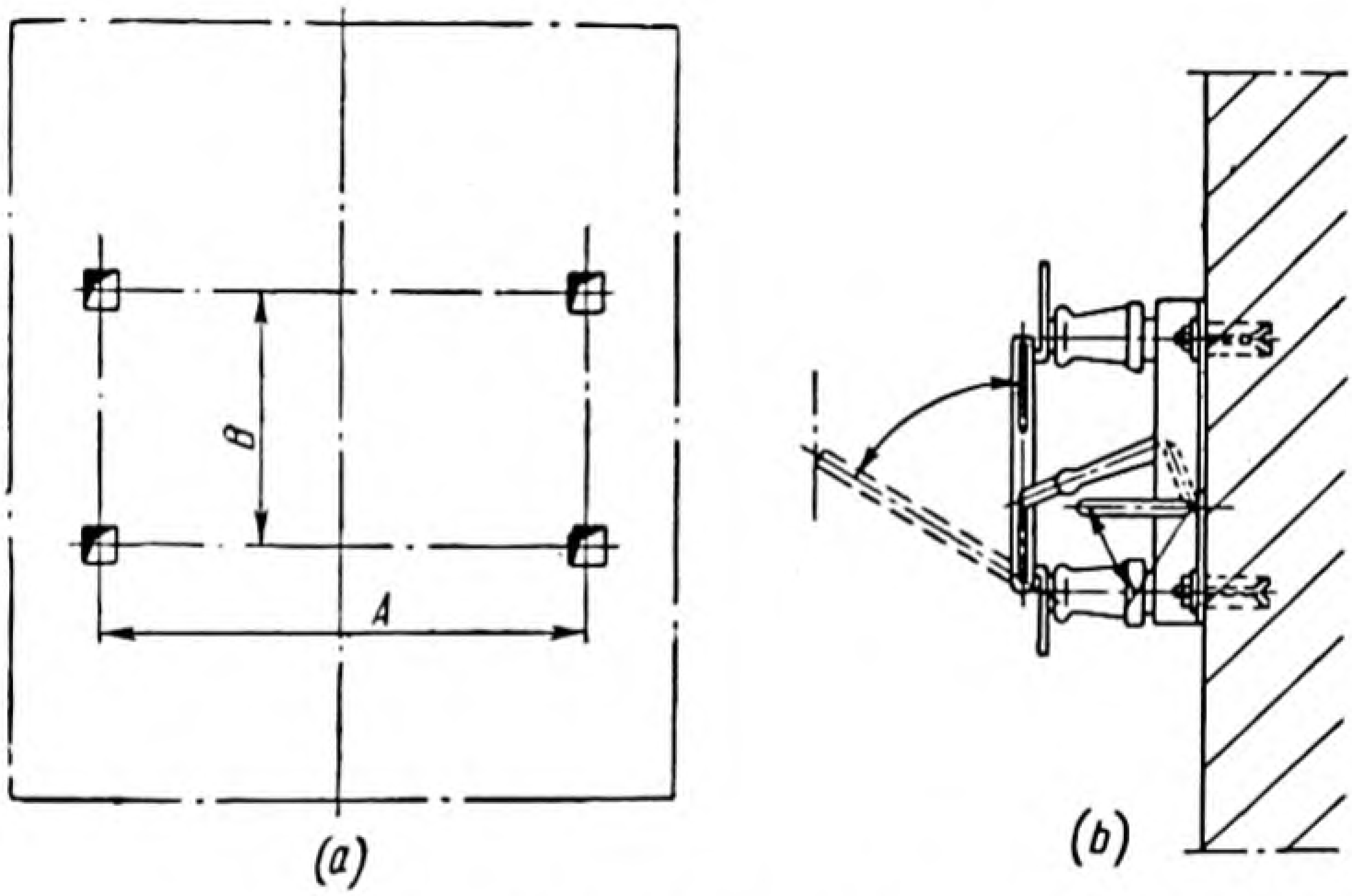


Fig. 50. Isolator mounting:
a—marking out positions for mounting; b—isolator secured with anchor studs

The porcelain insulation of isolators must meet the same requirements as the porcelain of support insulators and bushings.

Mounting of isolators. The mounting of isolators includes the following operations:

(1) marking out of positions for an isolator;

(2) placement of fastenings or supports;

(3) lifting of the isolator onto its permanent position;

(4) alignment and levelling of the isolator and final fixing of its baseplate;

(5) adjustment of blade travel and checking of the contact surfaces;

(6) mounting of the operating mechanism and, where used, of intermediate-linkage bearings;

(7) mounting of auxiliary switches (interlocks);

(8) coupling of the isolator to its operating mechanism and auxiliary switch;

(9) earthing of the isolator and its operating mechanism;

(10) overall adjustment.

An example of marking out the position for an isolator is illustrated in Fig. 50*a*.

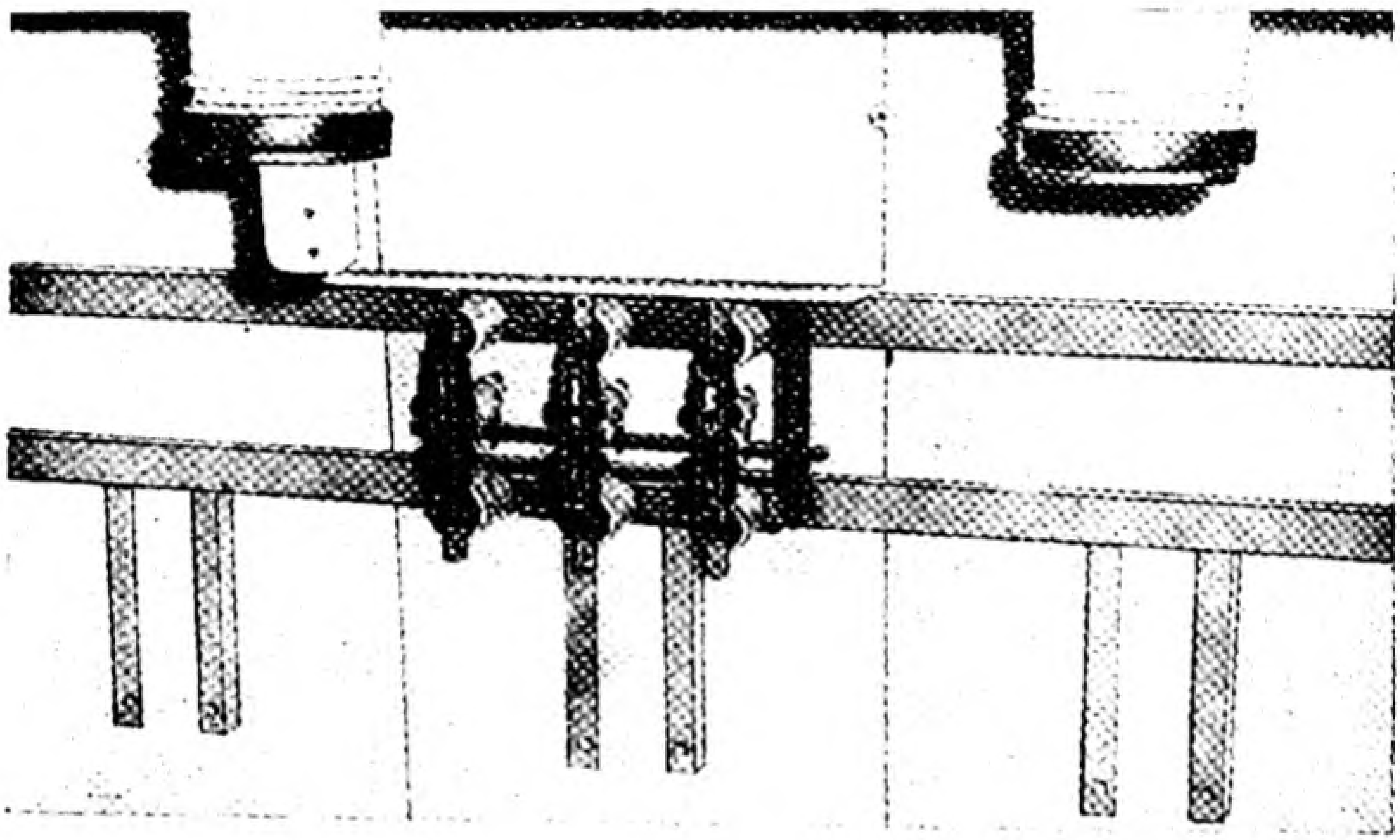


Fig. 51. Isolator mounted on metal supports in a substation assembled from precast elements (in process of work)

Isolators are fixed with anchor studs (Fig. 50*b*) on a brickwork base and with through bolts or studs on a concrete base. Isolators may also be mounted on metal supports made from angles or channels. Examples of isolators mounted on metal supports are given in Figs 51 and 52.

Isolators are lifted in place by hand to heights up to 1.5 metres, and with chain hoists or block and tackle to greater heights.

A lifted isolator is then temporarily secured in place with nuts run down their studs or bolts and aligned with respect to the laid-out horizontal and transverse axes with a plumb-bob, and a straight edge and spirit level. Misalignment is eliminated by inserting steel shims under the base plate where necessary. When aligning and

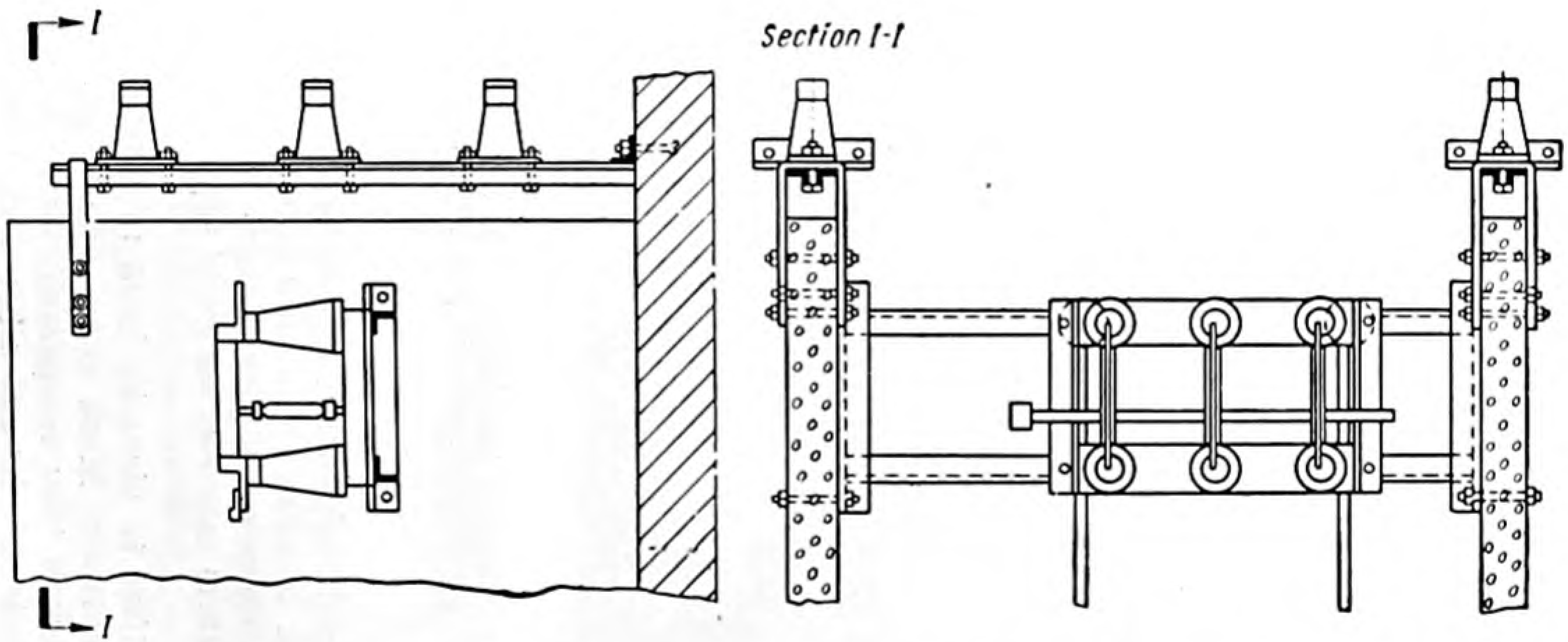


Fig. 52. **Isolator mounted on metal support in conventional concrete partition cell**

levelling, the shaft should be checked for free movement when operated by hand.

The isolator can next be finally clamped down by gradually tightening the nuts across in turn.

Since in the process of installation the isolator contact system may become maladjusted, it is necessary to make sure that the blades make contact smoothly, that the angle of blade rotation corresponds to the one specified by the manufacturer, etc., following the procedure outlined above.

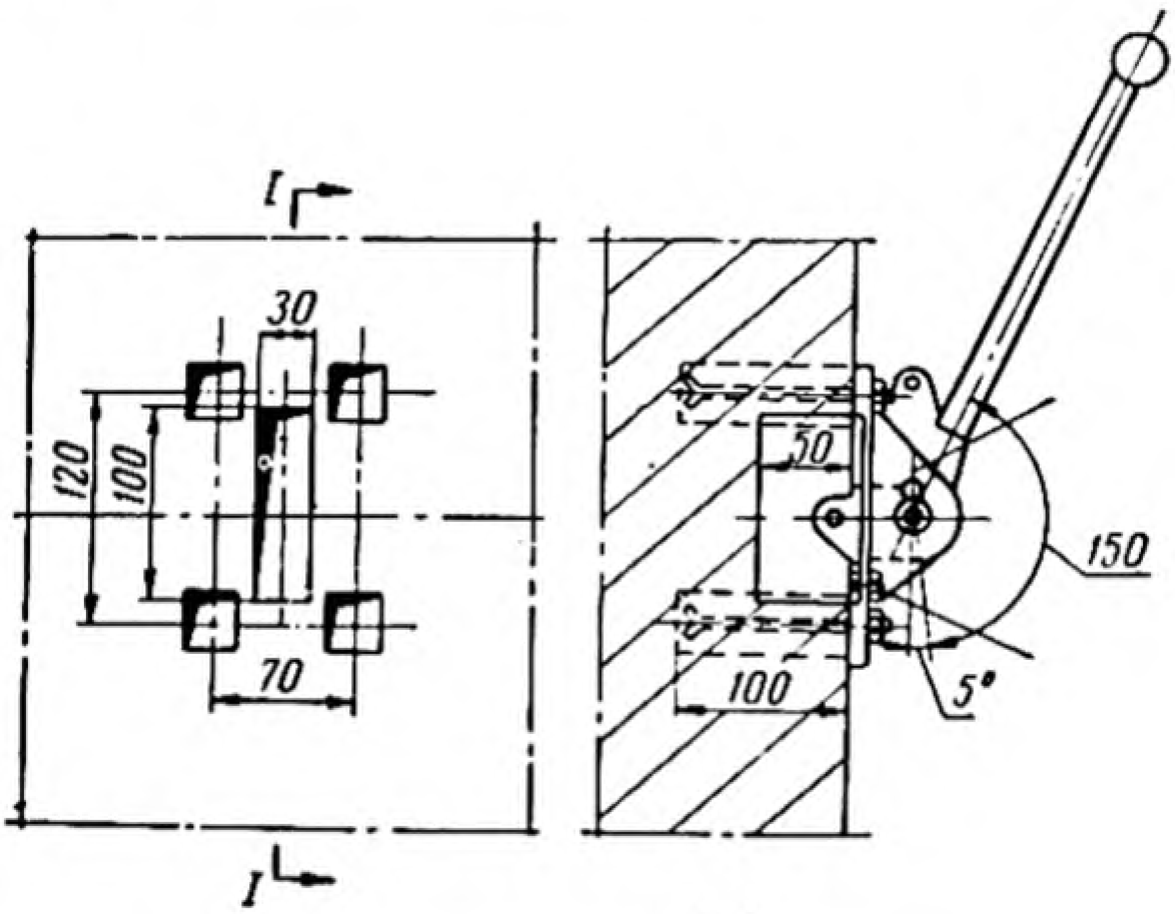


Fig. 53. Mounting of operating mechanism:
a — hole and opening layout for the ПР-2 operating mechanism; *b* — operating mechanism secured on brick wall

Isolators and their operating mechanisms are mounted at the same time. Fig. 53 shows a hand-operated ПР-2 lever operating mechanism. It has a weight of 3 kg. The figure also shows the mounting layout for this mechanism, which may be fixed with anchor studs when mounted in the same plane with the isolator or with through bolts when mounted in a different plane.

The isolator is coupled to its operating mechanism with a tubular tie rod (Fig. 54) made from ³/₄-inch steel pipe. The ends of the rod have adjusting clevises *6*. Isolators are furnished without tie rods, and they have to be made either in workshops, or on the installation site.

A tie rod is made to a dummy tie made from wire 5 or 6 mm in dia, bent to the shape given in the working drawing. The clevis

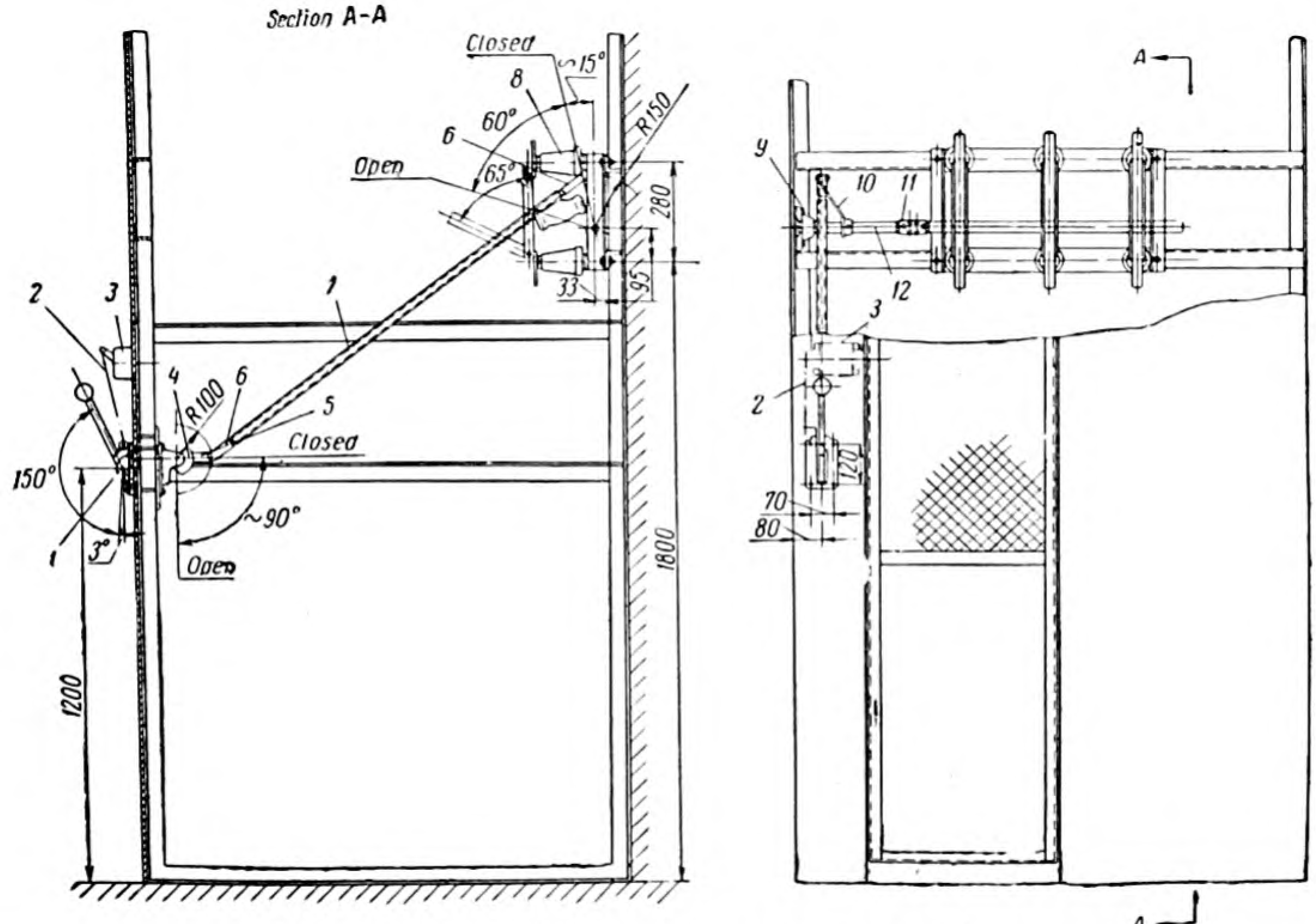


Fig. 54. Coupling of isolator to its operating mechanism:

1—operating mechanism; 2—tie bar to KCA auxiliary switch; 3—auxiliary switch; 4—operating mechanism sector lever; 5—lever of operating mechanism; 6—adjusting clevis; 7—tie rod; 8—isolator; 9—auxiliary bearing; 10—isolator actuating lever; 11—coupling between isolator shaft to extension shaft; 12—extension shaft

bolts, usually furnished by the manufacturer, are either welded or pinned into the ends of the rod.

The clevises are then hinged to the lever *10* on the isolator shaft and the lever *5* of the operating mechanism.

A short link *2* of steel strip links the operating handle with a KCA auxiliary switch *3* which contains two pairs of alternately closing contacts. One pair closes when the isolator operating handle is turned up, and the other pair closes when the handle is turned down, thus completing the circuits which show if the isolator is open or closed. The operating principle of KCA auxiliary switches can be understood from Fig. 55.

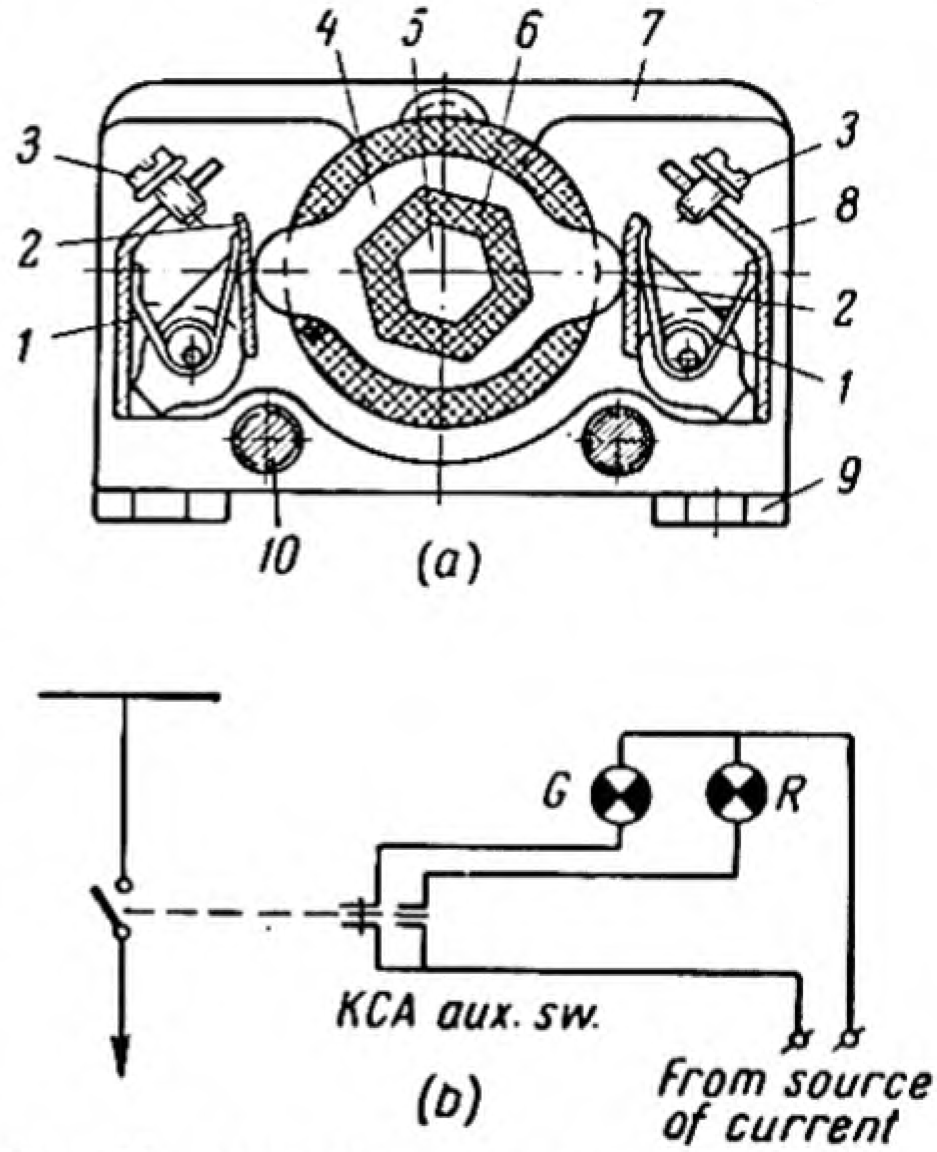


Fig. 55. Operating principle of the KCA auxiliary switch:

a—cross section through one circuit way; *1*—spring; *2*—fixed contact; *3*—terminal screw; *4*—moving contact; *5*—shaft; *6*—moulded-plastic washer; *7*—steel case; *8*—moulded-plastic body; *9*—case foot; *10*—clamping studs; *b*—isolator position signalling circuit

After an isolator has been coupled with its operating mechanism, and the latter has been linked with the auxiliary switch, the entire system is aligned. Satisfactory joint operation of the isolator and the operating mechanism is first attained, after which the auxiliary switch is adjusted.

An adjusted isolator, together with its operating mechanism and auxiliary switch must meet the following requirements:

(1) an isolator should close or open on one swing of the operating handle, smoothly, without jerking or striking in the contact system;

(2) a full stroke of the operating handle should move the blade through the angle specified by the manufacturer (see Table 8) on both a closing and an opening operation;

(3) the lost motion of the operating handle should not exceed 3 degrees both in closing and opening;

(4) on a closing stroke the auxiliary switch contacts should make or break after the blades and fixed contacts have met and the blades have turned through not less than 5 degrees;

(5) on an opening stroke the auxiliary switch contacts should make or break after the isolator blades have covered 75 per cent of their travel.

When an isolator is actuated by a worm-gear operating mechanism (Fig. 56), the crank of the latter should be able to rotate fully clockwise to close the isolator, and fully counterclockwise to open the isolator. The tolerance in both cases is ± 3 mm.

After overall adjustment the isolator should be given 20 to 30 trial openings and closings. At the same time the rubbing parts and

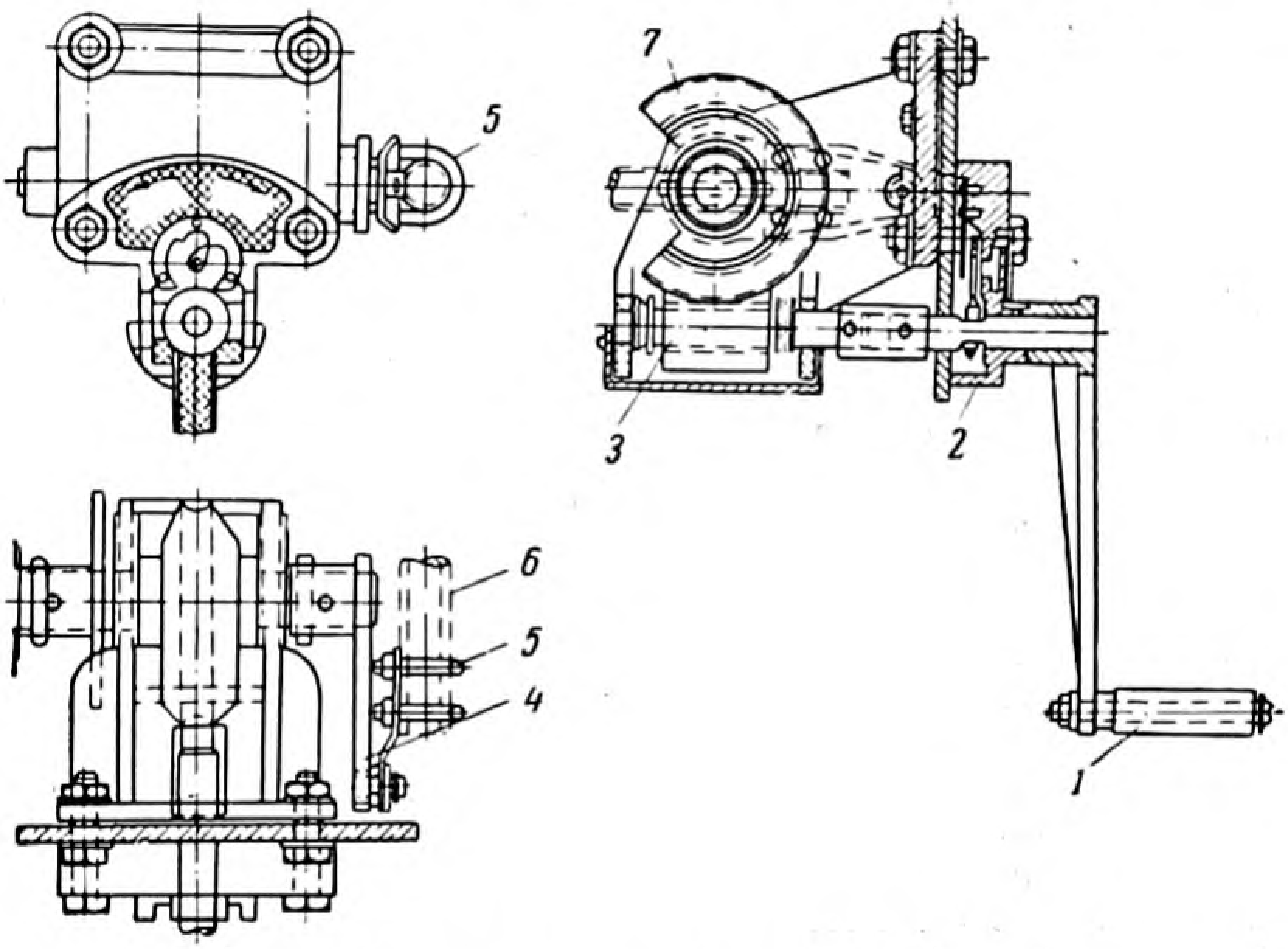


Fig. 56. Isolator worm-gear operating mechanism:
1—crank arm; 2—body; 3—worm; 4—lever; 5—clip for attaching tie rod; 6—tie rod to isolator; 7—worm gear

contacts should be wiped with a rag moistened with petrol, then with a dry rag, and lubricated with petroleum jelly. The rubbing surfaces of the purely mechanical linkages should be lubricated with grease. The greased parts should be wrapped in paper to shut out dirt and dust during installation.

Problem. Write up an operation sequence for mounting an isolator according to the drawing in Fig. 52. The card should contain all operations, including marking out the position of the isolator.

11. Mounting of Load-breaking Isolators

In circuits operating at 6 to 10 kv and up to 400 a the relatively small load currents are interrupted by load-breaking switches, such as ВН-16 and ВНП-16 switches.

The principal installation dimensions of a ВНП-16 isolator which weighs 64 kg are given in Fig. 57 and Table 9, and its general view, in Fig. 58.

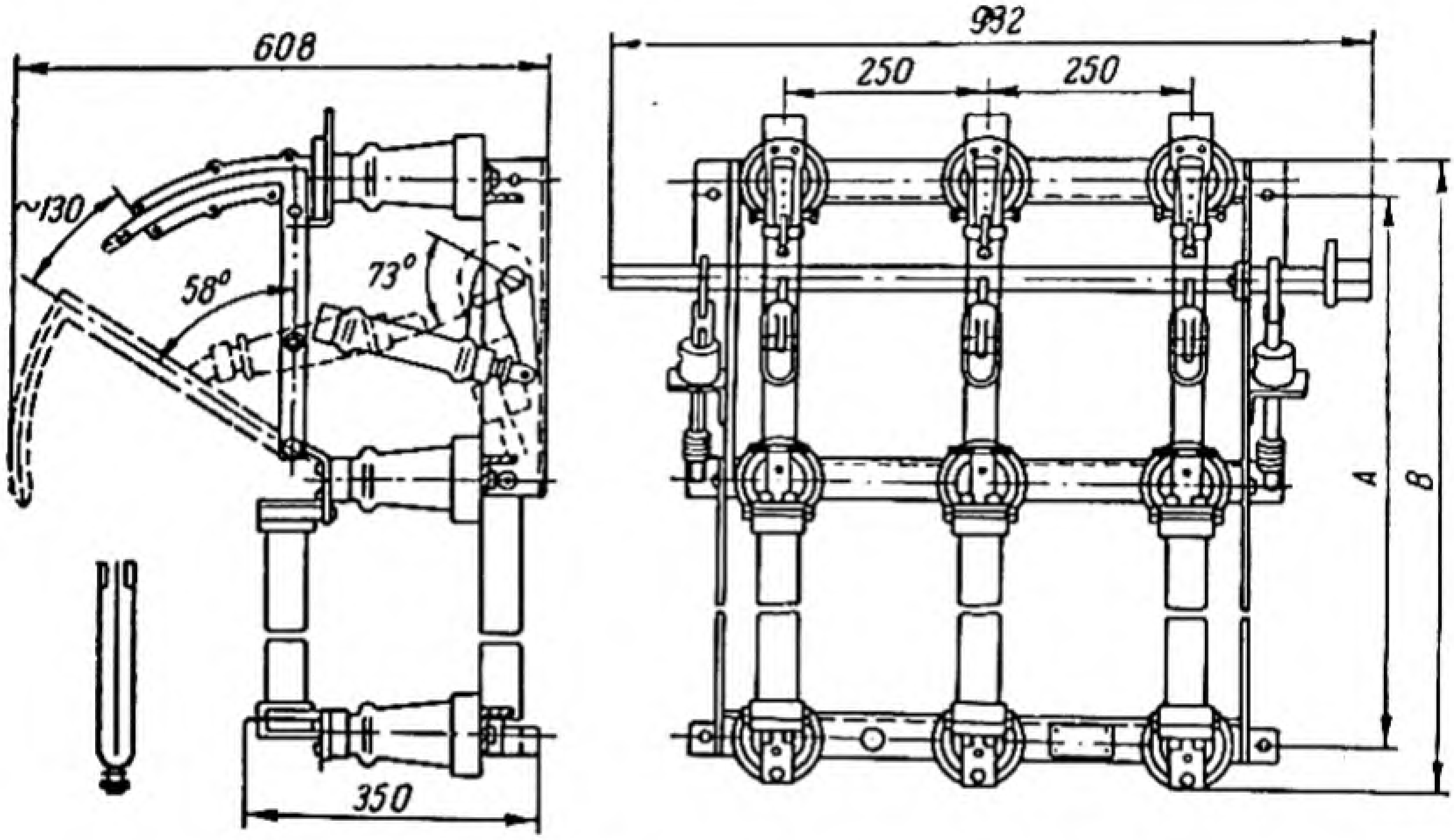


Fig. 57. ВНП-16 load-breaking isolator

Table 9

Principal Dimensions of ВНП-16 Load-breaking Isolators

Dimensions (Fig. 57)	Dimensions by fuse type, mm					
	ПК-6/30	ПК-6/75	ПК-6/150	ПК-10/30	ПК-10/50	ПК-10/100
A	703	758	758	803	858	858
B	870	925	925	970	1,025	1,025

Before mounting, a load-breaking isolator should be inspected externally, much as any other isolator. Additionally, its plastic arc chutes *2* are checked for breaks and cracks (see Fig. 58) and for missing gas-generating packs *3*. It is very important that the arcing contacts *4* are not bent and that they enter the gas-generating packs easily and positively.

The installation procedure for a load-breaking isolator is generally the same as for an ordinary isolator.

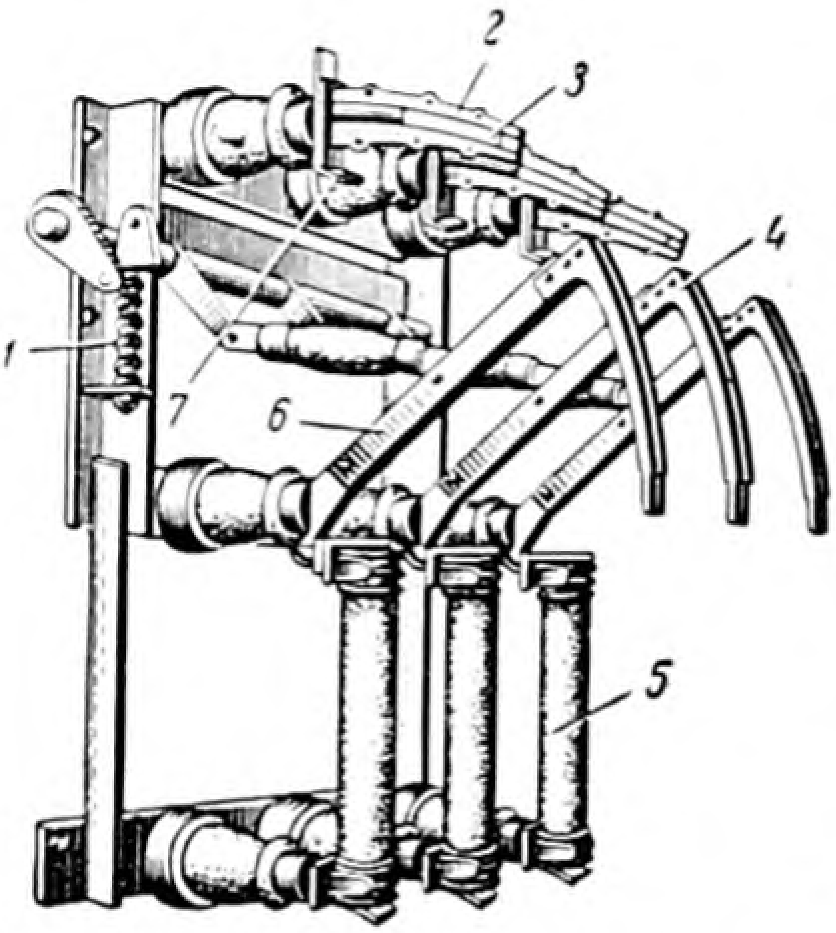


Fig. 58. General view of ВНП-16 load-breaking isolator:

1—opening spring; *2*—plastic arc chutes; *3*—plastic gas-generating pack; *4*—arcing contact blade; *5*—fuse; *6* and *7*—load-carrying contacts

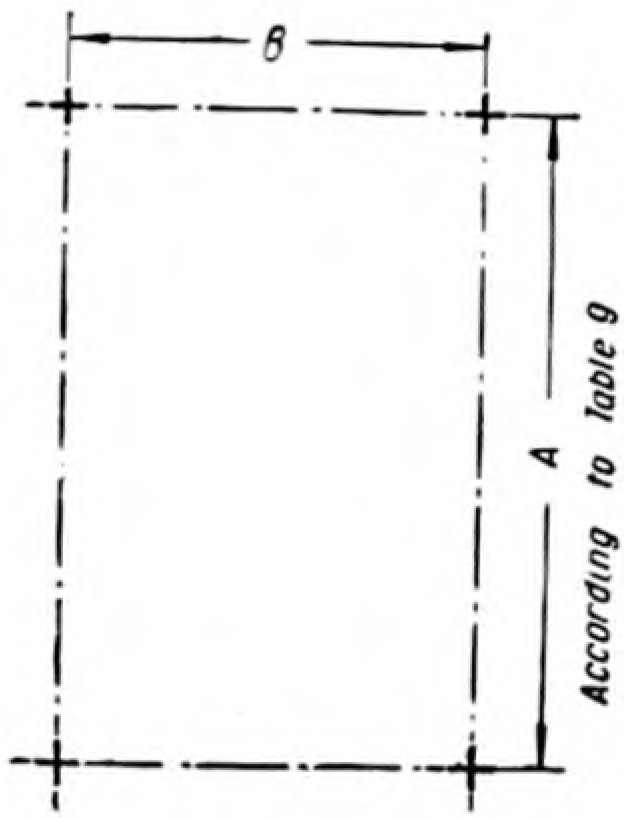


Fig. 59. Layout sketch for the ВНП-16 isolator

Its permanent position is first marked out according to a sketch as shown in Fig. 59, and the fastenings, which may be either anchor studs or M16-bolts, are installed.

Then the isolator is lifted in position, temporarily secured, and then plumbed and levelled.

When plumbing and levelling, care must be taken that the contact assembly, especially its arc-control devices, operates positively and smoothly. This is checked by opening and closing the moving system of the apparatus by hand.

The operating mechanism of a load-breaking isolator is mounted when the isolator is in place. The operating mechanism generally employed is the ПРА-12 weighing 6 kg (Fig. 60*a*).

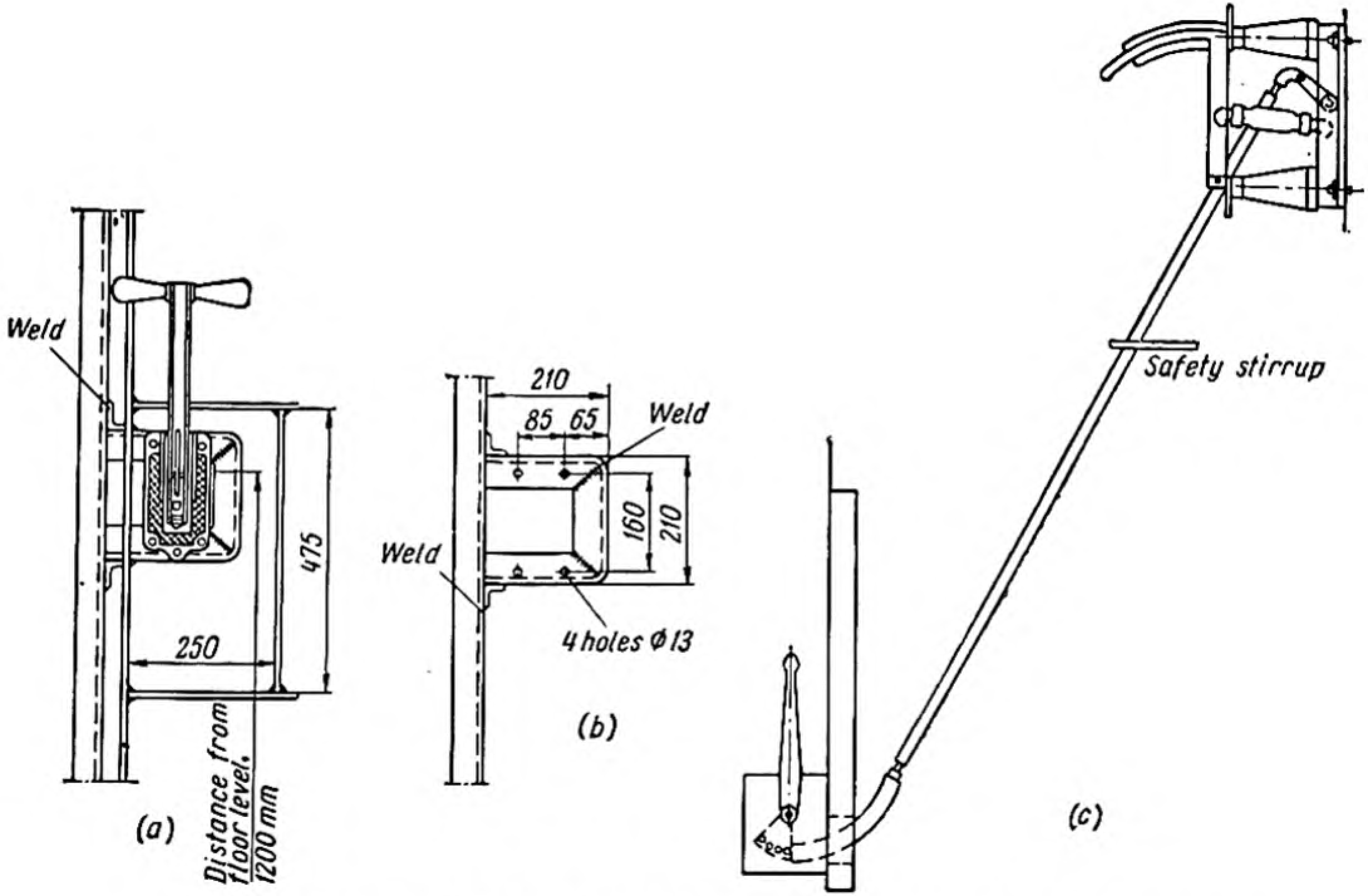


Fig. 60. Connection of a load-breaking isolator with its operating mechanism:
a—operating mechanism in place; *b*—bracket; *c*—isolator connected to its operating mechanism

It is usually mounted on an angle iron bracket grouted in as shown in Fig. 60*b*.

The isolator is coupled with its operating mechanism by means of a tie rod made from $^3/_4$-inch steel pipe (Fig. 60*c*). Adjusting clevises are either pinned or welded to both ends of the tie-rod pipe.

A load-breaking isolator and its operating mechanism are aligned for joint operation much as a three-pole isolator is, but main emphasis is placed on the arcing contacts which should enter the plastic arc chambers and the fixed jaws freely and precisely.

A precaution always to be observed in adjustment is that

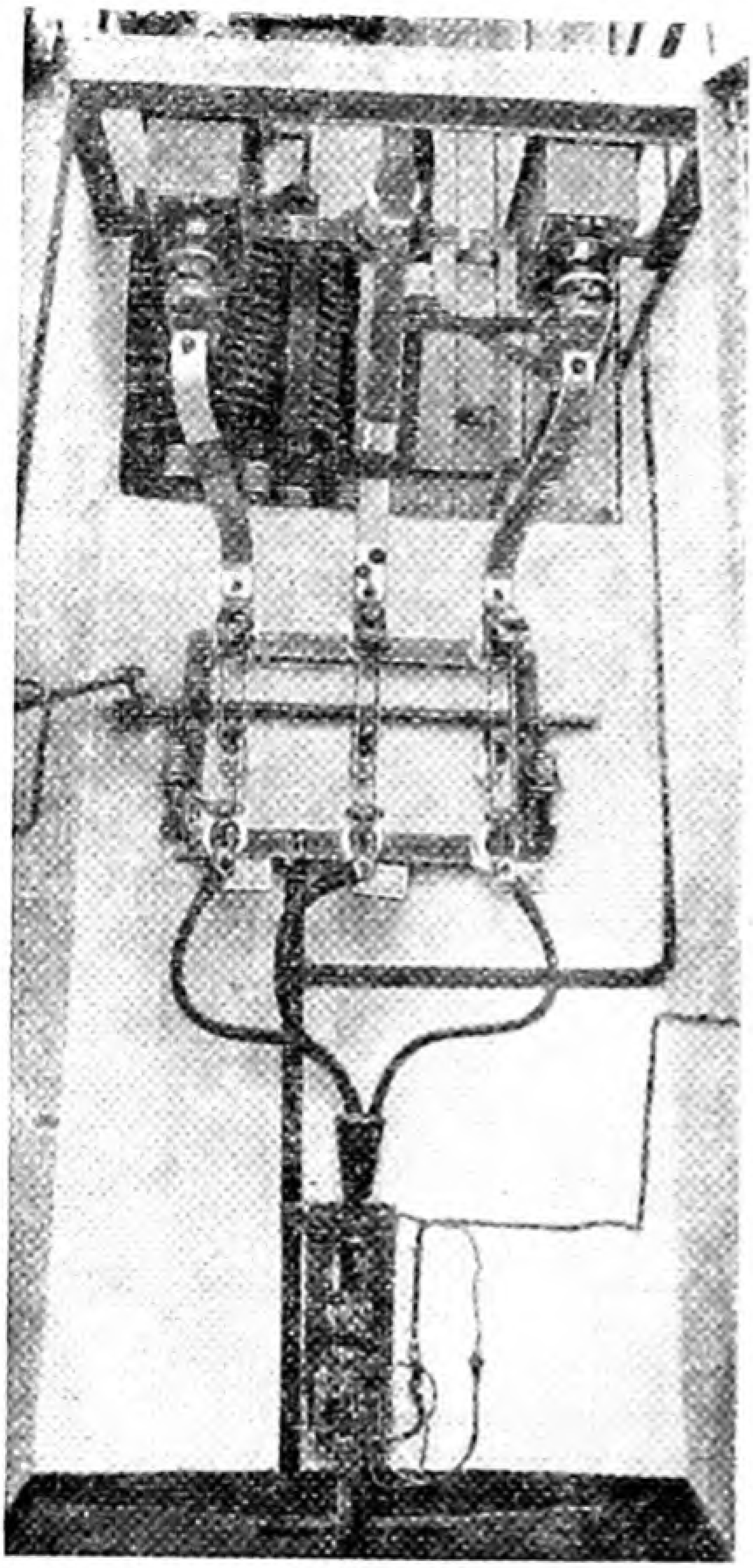


Fig. 61. BH-16 load-breaking isolator in a switchgear cell

when the operating mechanism is being actuated, the arcing blades must never be touched, or else grave injury may result.

After installation, the contacts of the apparatus should be given a thin coat of petroleum jelly, and all rubbing parts of the switch and operating mechanism should be lubricated with grease.

The final operation is to give the isolator ten trial closings, after which it may be handed over for service.

Problem. Using Fig. 61 for reference, write up a sequence of operations for a BH-16 load-breaking isolator to be installed in a switchgear cell.

12. Mounting of ВГ-10 Hard-gas Circuit Breakers

ВГ-10 hard-gas breakers are based on the same principle as the load-breaking isolators discussed in the preceding section. They differ however in that they have more powerful cross-blast arc-control chambers. These circuit breakers are rated for voltages up to 10 kv

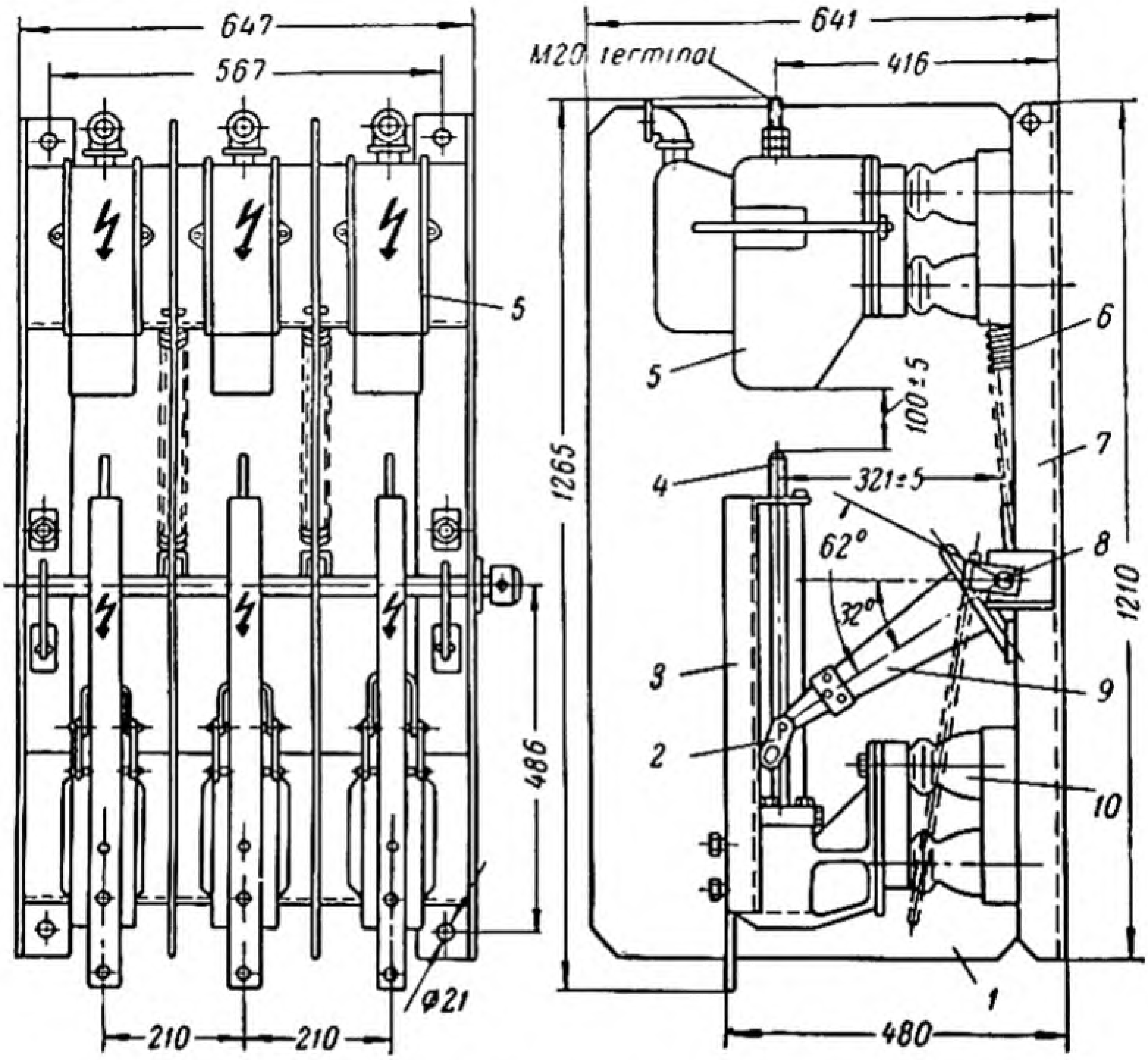


Fig. 62. ВГ-10 hard-gas circuit breaker:

1—barrier; 2—shackle; 3—guide assembly; 4—contact blade; 5—arc-control chamber; 6—opening spring; 7—welded steel frame; 8—circuit-breaker shaft; 9—contact blade operating lever; 10—double-insulator support

and currents up to 400 a. The main overall and installation dimensions are given in Fig. 62; a cross section through the arc-control chamber can be seen in Fig. 63. This circuit breaker weighs 300 kg.

The ВГ-10 circuit breaker comes from the manufacturer's works fully assembled and adjusted. It is mounted with M12 studs on brickwork or concrete structural members, and with bolts on metal supports.

The circuit breaker is lifted into its permanent position with block and tackle. After plumbing and levelling, it is finally clamped down by its fixing bolts. During mounting, the blades *4* (Fig. 62) should be checked to see that they enter the throats of the arc-control chambers *5* properly, and that the breaker mechanism does not seize.

The ВГ-10 hard-gas circuit breaker is operated by a ППР-21 spring-loaded lever mechanism (Fig. 64) which weighs 19 kg.

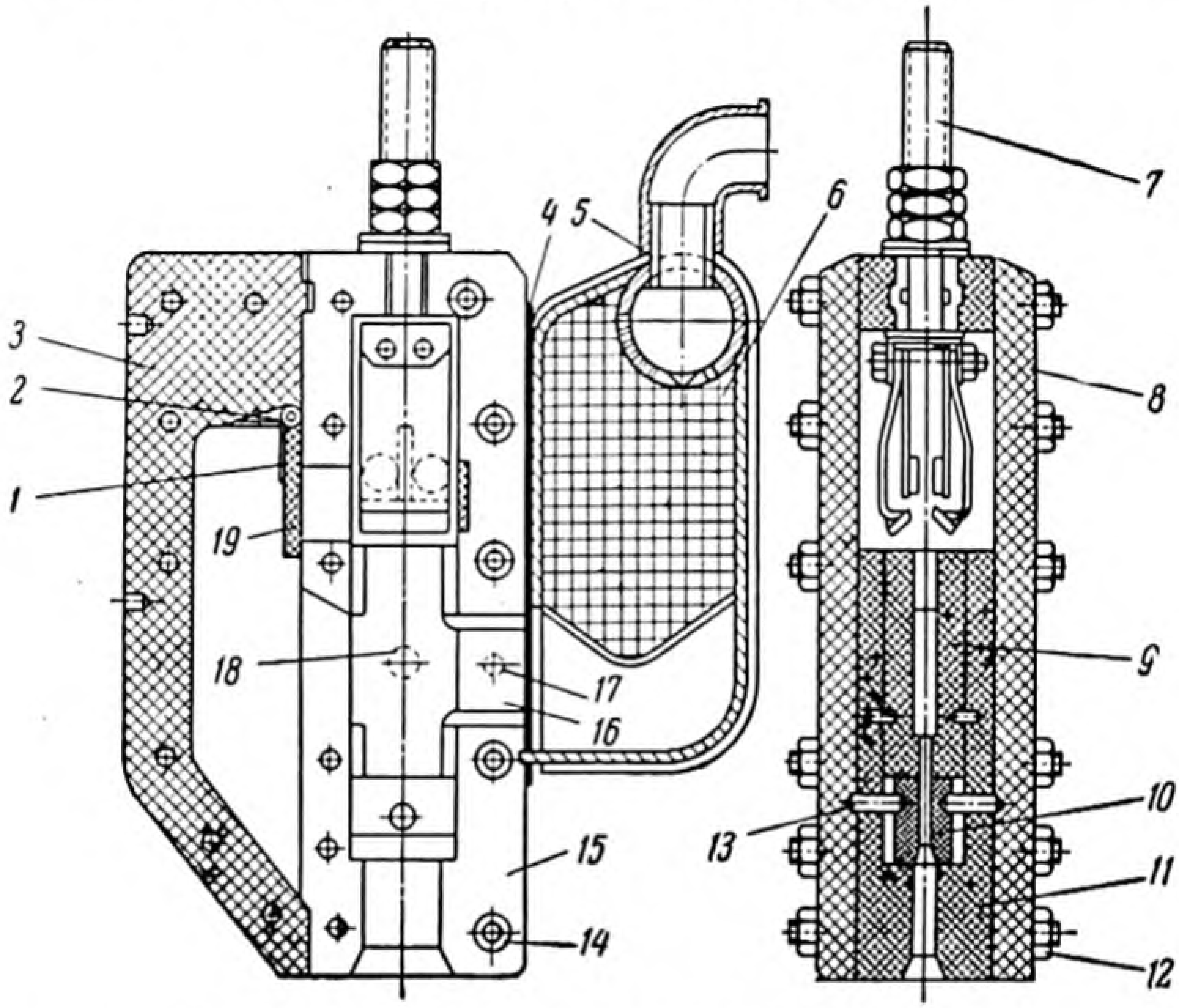


Fig. 63. Arc-control chamber of the ВГ-10 breaker:

1—spring; *2*—valve pin; *3*—textolite wall; *4*—gasket; *5*—gas vent; *6*—cooling tubes; *7*—base of fixed contact; *8*—cheek of paper-laminate; *9*—insert; *10*—gate of organic glass; *11*—cheek of organic glass; *12*—stud; *13*—spring; *14*—p.v.c. tubes; *15* and *16*—insert blocks; *17* and *18*—pins; *19*—flap valve

In mounting the ППР-21 operating mechanism, the last to be installed is its ПР-3В spring-loader *18*, which is followed by a strut *1*, fitted between them. The strut is made from 50×10 mm steel strip and gives the entire assembly greater rigidity. It should be fitted so as not to misalign the system. The operating mechanism and the spring-loader are coupled together by a tie rod *2* of such a length that when the lever is up the clearance between the pusher *6* and the ratchet *11* is about 6 mm.

The operating mechanism is then coupled to the shaft *8* (see O_1 in Fig. 64) of the circuit breaker by means of an arm *13*. Simultaneously

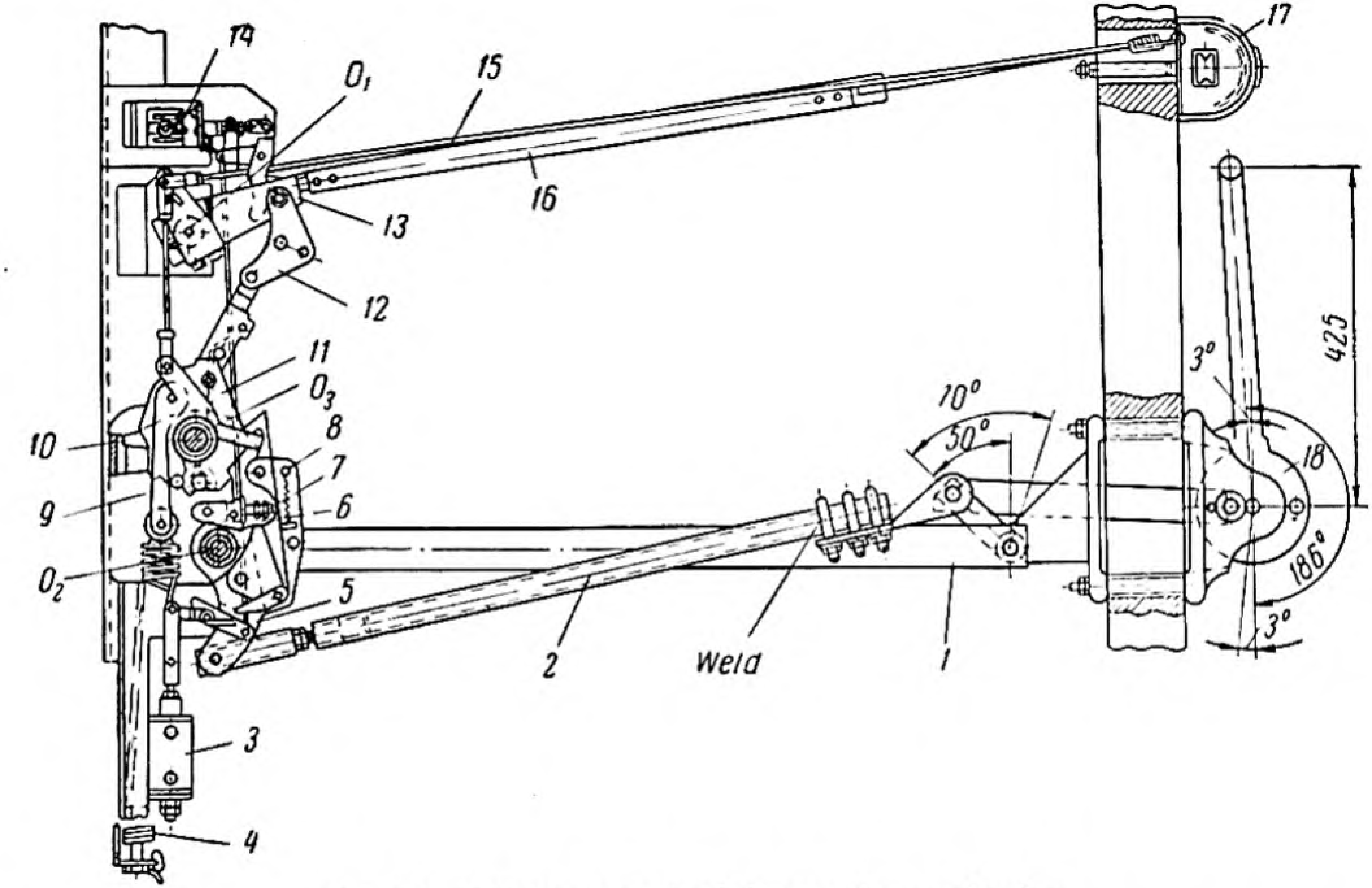


Fig. 64. ППР-21 spring-loaded operating mechanism:

1—strut; *2*—tie rod; *3*—closing electromagnet; *4*—closing spring; *5*—loading lever; *6*—pusher; *7*—screw for adjusting pusher position; *8*—closing trip-free mechanism; *9*—tie rod; *10*—closing lever; *11*—ratchet; *12*—opening trip-free mechanism; *13*—arm connected with breaker shaft; *14*—opening elements unit; *15*—position indicator tie rod; *16*—manual control tie rod; *17*—control and signal unit; *18*—ПР-3В spring loader; O_1—breaker shaft; O_2—loading lever shaft; O_3—closing lever shaft

the control and signal unit *17* is mounted and linked with the operating mechanism by means of the position-indicator tie rod *15* and the manual-operation tie rod *16*.

When the circuit breaker and its operating mechanism are being adjusted for joint operation, the closing spring *4* is loaded by giving the loading handle two strokes down and two strokes up. This will rotate the loading lever *5* about the axis O_2, causing the closing trip-free mechanism *8* to turn the ratchet *11* through an angle close to 90 degrees. The tie rod *9* pivoted to the ratchet will then change its position, thus stretching and loading the closing spring *4*. A latch holds the ratchet in the new position and the operating mechanism is now ready for operation.

The operating mechanism can be remotely controlled by energising the electromagnet *3* which then pulls in its armature and releases the latch of the closing trip-free mechanism *8*. Now the ratchet *11* is free to engage and turn the closing lever *10* under the action of the closing spring *4* counterclockwise, thus closing the breaker through the arm *13* which is coupled with the lever *10*.

Closing by hand is accomplished from the control and signal unit *17* through the tie rod *16* and a leverage.

In the case of remote control and automatic opening, one of the trip coils in the unit *14* of the operating mechanism is energised to release the opening trip-free mechanism *12*. Manual opening is accomplished from the control and signal unit by means of the same leverage as in closing.

The tie rod *16* with which the circuit breaker is closed or opened manually should be so adjusted in length that the small cast-iron lever on the unit is in a horizontal position when free. When it is lifted, the breaker should close, when lowered, the breaker should open.

The length of the tie rod *15* which controls the position indicating target should be adjusted so that the inscriptions on the indicator agree with the actual position of the circuit breaker.

When adjusting the breaker and its operating mechanism for joint operation, the distance between the end of the blade *4* (see Fig. 62) and the undersurface of arc-control chamber *5* must be kept within 95 and 105 mm, with the breaker fully opened.

In the course of erection, pipes extending to the atmosphere outside the substation building are fitted to the gas vents. Where several hard-gas circuit breakers are installed in a row, a common vent header is provided and the individual gas vents are connected to it.

Problem. Write up the mounting procedure for a ВГ-10 hard-gas circuit breaker.

13. Mounting of ВМБ-10 Oil Circuit Breakers

The ВМБ-10 is a single-tank oil circuit breaker of the 10-kv class available in current ratings from 200 to 1,000 amperes. It has a dry weight of 120 kg and takes 50 kg of oil. For its installation dimensions and design features refer to Fig. 65.

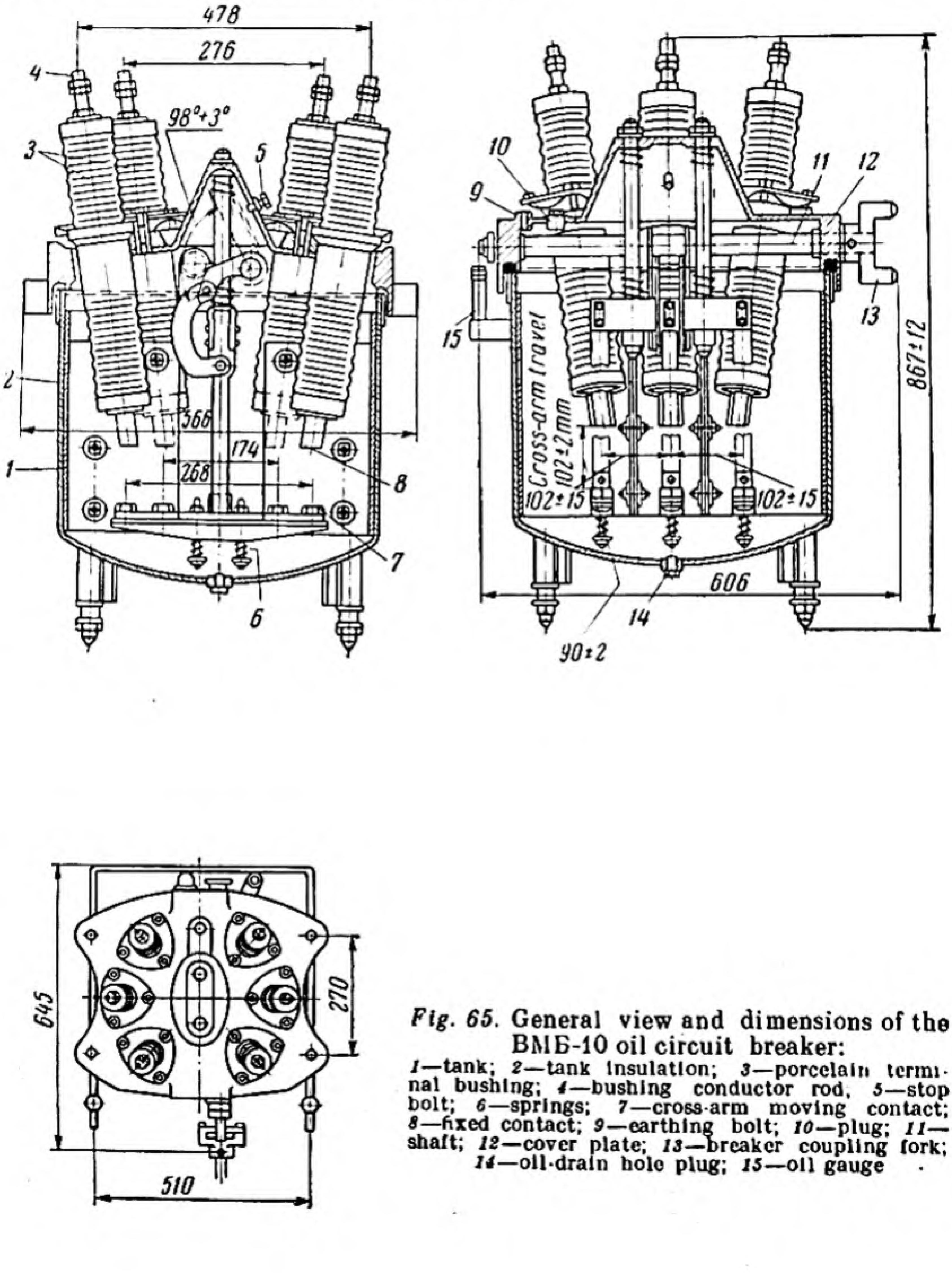


Fig. 65. General view and dimensions of the ВМБ-10 oil circuit breaker:
1—tank; *2*—tank insulation; *3*—porcelain terminal bushing; *4*—bushing conductor rod, *5*—stop bolt; *6*—springs; *7*—cross-arm moving contact; *8*—fixed contact; *9*—earthing bolt; *10*—plug; *11*—shaft; *12*—cover plate; *13*—breaker coupling fork; *14*—oil-drain hole plug; *15*—oil gauge

ВМБ-10 oil circuit breakers come from the manufacturer fully assembled, but without oil. They are installed on a metal support made from 50×50 mm angles, such as shown in Fig. 66. A circuit breaker is lifted onto the support with a half-ton block and tackle or with the aid of a loading ramp.

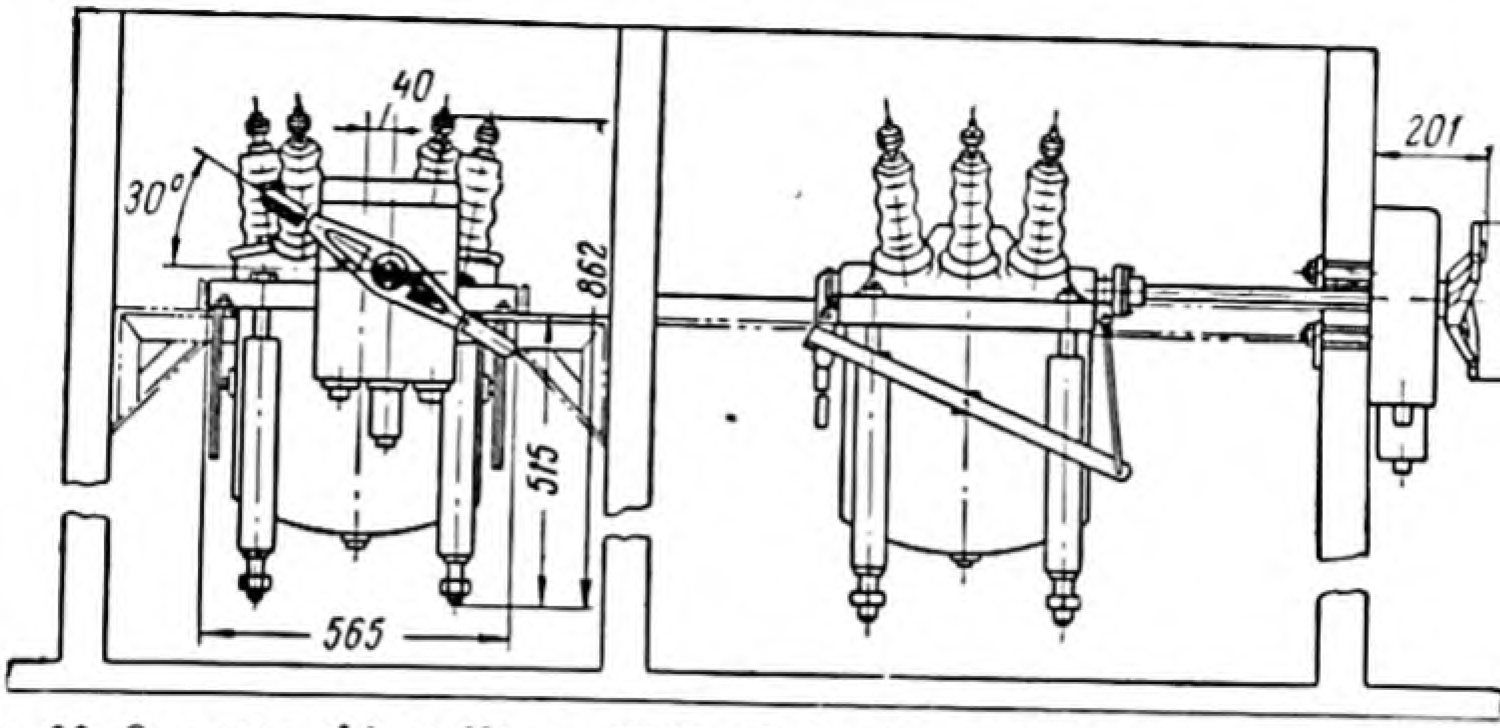


Fig. 66. One way of installing a ВМБ-10 oil circuit breaker on a metal framework

The support should be put in so that the axis of the circuit-breaker shaft is 70 mm above the top surface of the support and this surface is at least 1,050 mm above the floor of the cell so that the tank can be lowered when the circuit breaker is open.

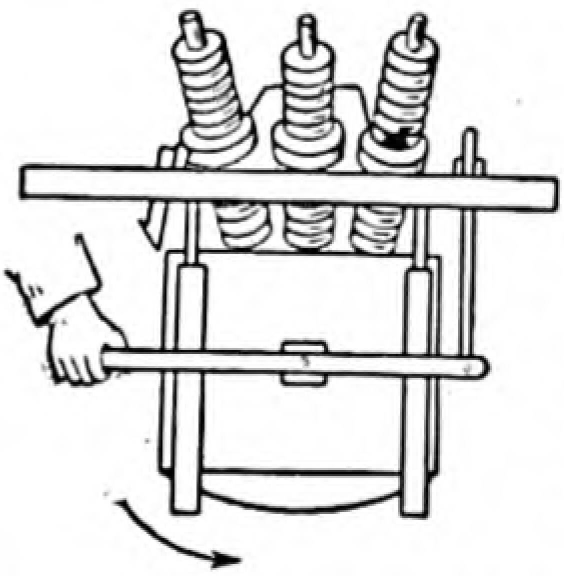


Fig. 67. Lowering of ВМБ-10 breaker tank

After the circuit breaker has been mounted in permanent position, its tank is lowered, using the lowering bars suspended from its top plate (Fig. 67).

The contacts of the circuit breaker are inspected to see that the lower bevelled ends of the fixed contacts *8* (see Fig. 65) are in a horizontal plane. If they are not, the respective bushings should be unbolted from the top plate and turned about their axes to bring the bevelled ends of the contacts into the proper position. Care must be taken that this does not change the angle that the bushings make with the axis of the circuit breaker.

ВМБ-10 oil circuit breakers use the manual ПРА-10 automatic operating mechanism shown in Fig. 68.

To couple the shafts of the circuit breaker and operating mechanism, their centre lines must be aligned to within ± 2 mm.

Adjustment of the breaker and operating mechanism for joint operation includes a check on the travel of the contact-carrying cross-

arm, which should be anywhere between 100 and 104 mm. When the circuit breaker is closed, the stroke is limited by a stop bolt *5* (see Fig. 65) screwed into the cover plate and fixed by its lock nut. This bolt prevents the operating mechanism from coming too close to the dead centre position.

Another point requiring checking is contact pressure. This is done by slowly closing the breaker until the contact *7* just touches the

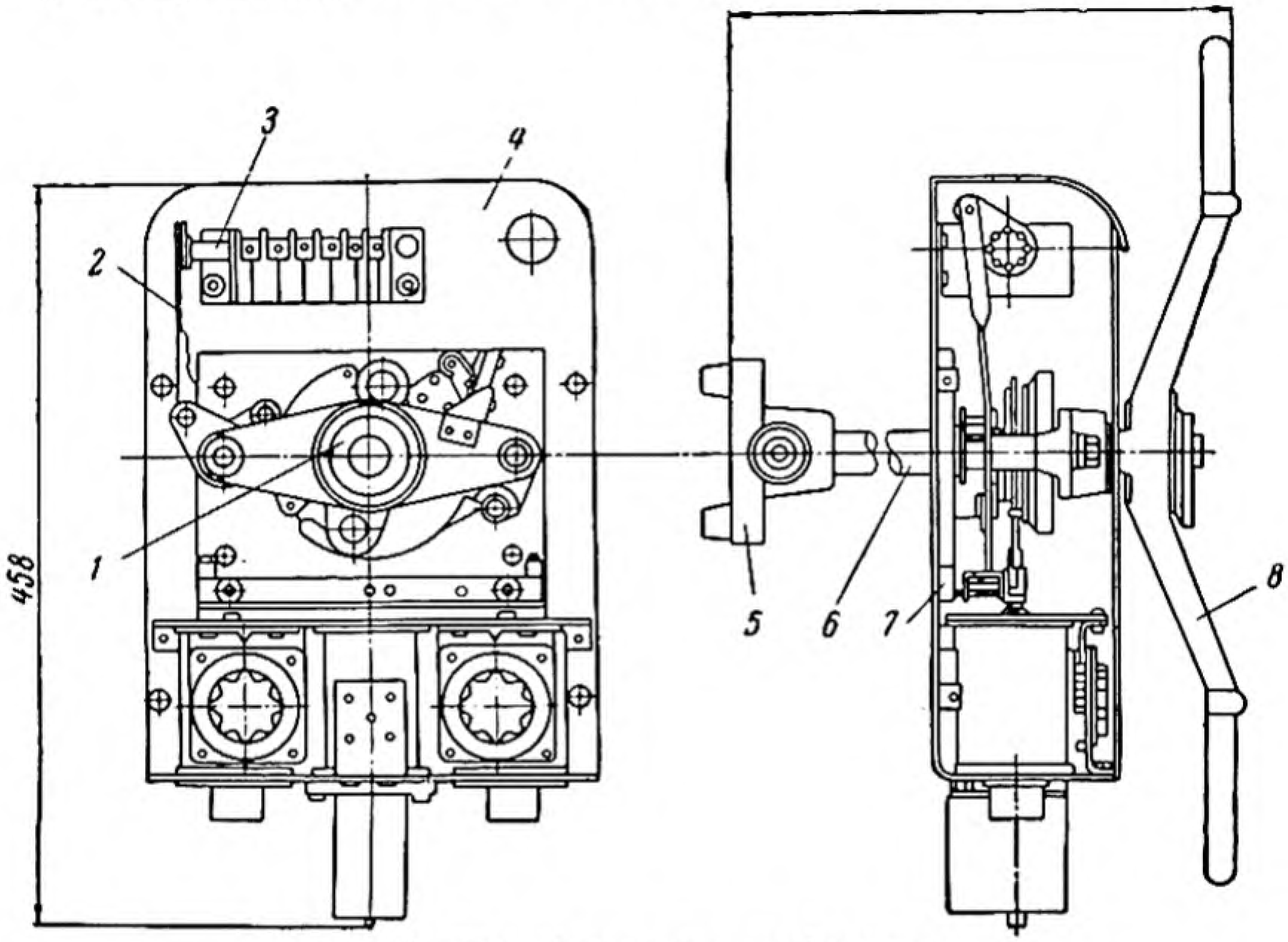


Fig. 68. ПРА-10 operating mechanism:
1—front bearing; *2*—link; *3*—interlocking contacts; *4*—mechanism frame; *5*—coupling fork; *6*—shaft; *7*—plate serving as rear bearing; *8*—two-arm operating lever

fixed contact. In this position a pencil mark is drawn on the insulating lift rod opposite the end of the fixed contact. The circuit breaker is then fully closed and a new mark is drawn on the lift rod. If the distance between both marks is from 11 to 13 mm, the travel inside the contacts is considered normal, and so is the contact pressure because a sufficient load is brought to bear on the springs *6*. Whenever necessary, the travel in the contacts, and, hence, their pressure can be adjusted by an angular shift of the operating mechanism shaft relative to the circuit breaker shaft.

The contacts are checked to see that they make and break simultaneously in each phase.

Finally, the circuit breaker and operating mechanism are checked to see that their closed and open positions fully agree. If a repeated check confirms that the stroke of the cross-arm and the travel within the contacts are correct, the shafts of the operating mechanism and circuit breaker may be coupled finally. The coupling fork on the operating mechanism shaft is locked with a taper pin 60 mm long and 8 mm in dia. The coupling fork on the circuit breaker shaft is usually pinned at the manufacturer's works.

Problem. Make a drawing and describe the fabrication of a metal framework for a ВМБ-10 oil circuit breaker in a 6-10 kv switchgear cell.

14. Mounting of ВМГ-133 Minimum-oil Circuit Breakers

The ВМГ-133 oil circuit breaker* is of the minimum-oil class of apparatus designed for indoor service in both heated and unheated locations. It is available in voltage ratings up to 10 kv and current ratings up to 600 amperes.

The main overall and installation dimensions and a general view of this type of circuit breaker are given in Figs 69 and 70, respectively, while Fig. 71 shows a section through one pole pot.

The circuit breaker has a dry weight of 180 kg, and its three pots take 10 kg of oil.

The circuit breaker to be installed is first unpacked and inspected for broken porcelain, oil-level indicators, and paint coverings, for traces of corrosion and any other external defects, and also for missing parts.

The mounting procedure. The first thing to do is to mark out positions for fastenings (Fig. 72). Where the circuit breaker is to be mounted on a brick wall, four M16 or M18 studs, 130 to 150 mm long, should be grouted in blind holes in the wall. In the case of a concrete partition, through bolts of the same size are used, with a length the thickness of the partition plus 50 mm. On a metal framework these circuit breakers are likewise secured with bolts.

Next, the breaker frame is lifted into place with a block and tackle to the upper part of the cell or, in some cases, by hand and slipped on the studs or bolts (Fig. 73).

The frame is temporarily secured at two upper points and is carefully plumbed and levelled. If the angle supports of the frame do not fit closely to the wall, split washers should be put on the bolts or studs in the gap between the frame and wall.

Now the nuts on the studs or bolts are tightened and the breaker shaft *7* is turned by hand to see that it does not bind (see Fig. 70).

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* The ВМГ-133-II modification is discussed here.

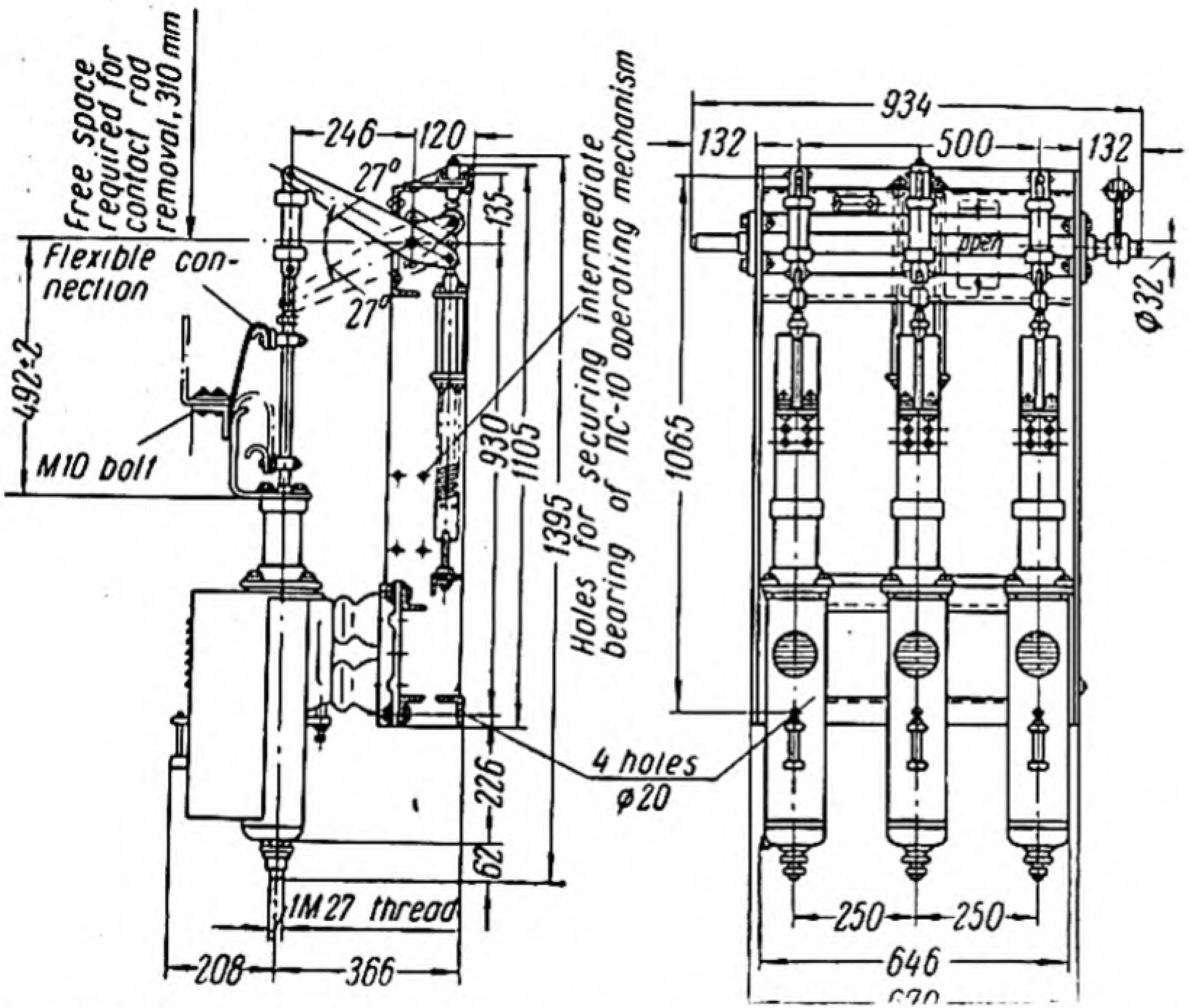


Fig. 69 Main and installation dimensions of the ВМГ-133 oil circuit breaker

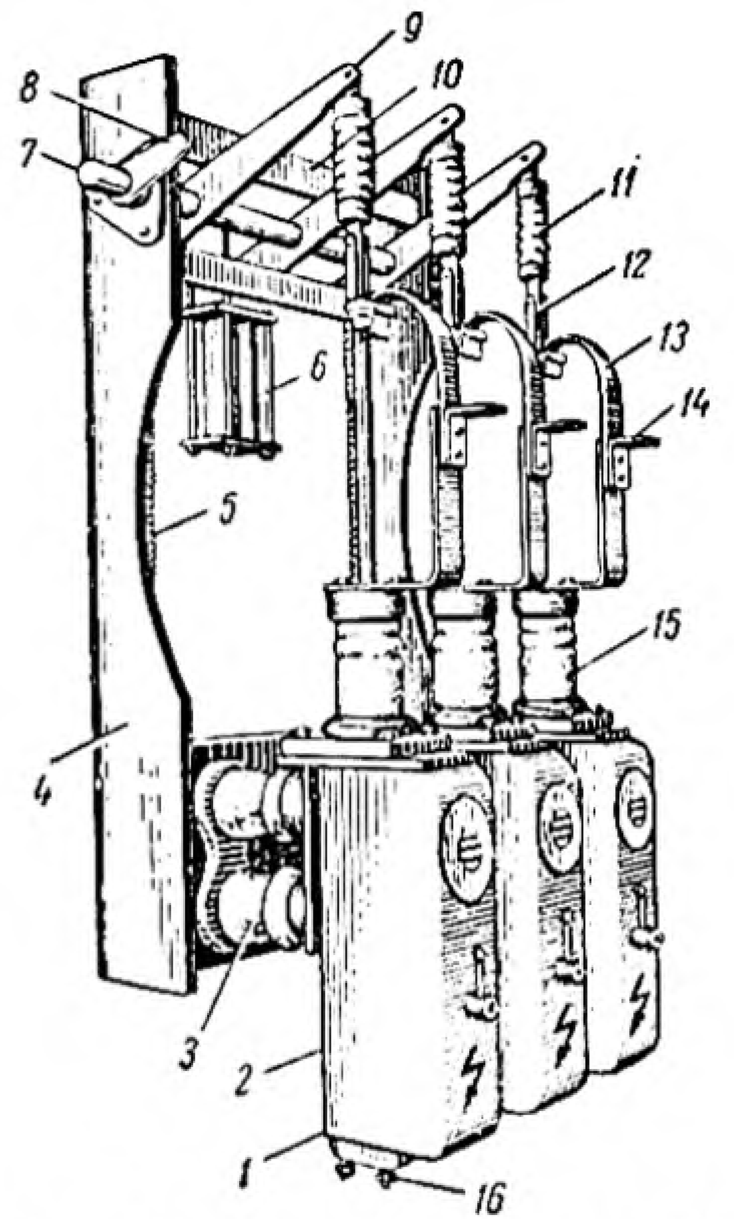


Fig. 70. General view of the ВМГ-133 oil circuit breaker:

1—bottom of pot; *2*—pot (cylinder); *3*—support insulators; *4*—frame; *5*—opening spring; *6*—oil dashpot; *7*—shaft; *8*—actuating arm; *9*—two-arm lever; *10*—point of mounting of spring buffer; *11*—porcelain tie rod; *12*—contact rod; *13*—flexible connection; *14*—connecting lug; *15*—bushing insulator; *16*—cluster contact shank

Any binding of the shaft is a sign that the frame is not set straight. This must be eliminated before the nuts are finally screwed tight.

After the frame has been mounted, the pots *2* (Fig. 70) are mounted and the moving contact rods *12* are checked to see that they will drop by gravity from a height corresponding to the open position of the breaker and enter the cluster contacts *16* by at least 40 mm. If

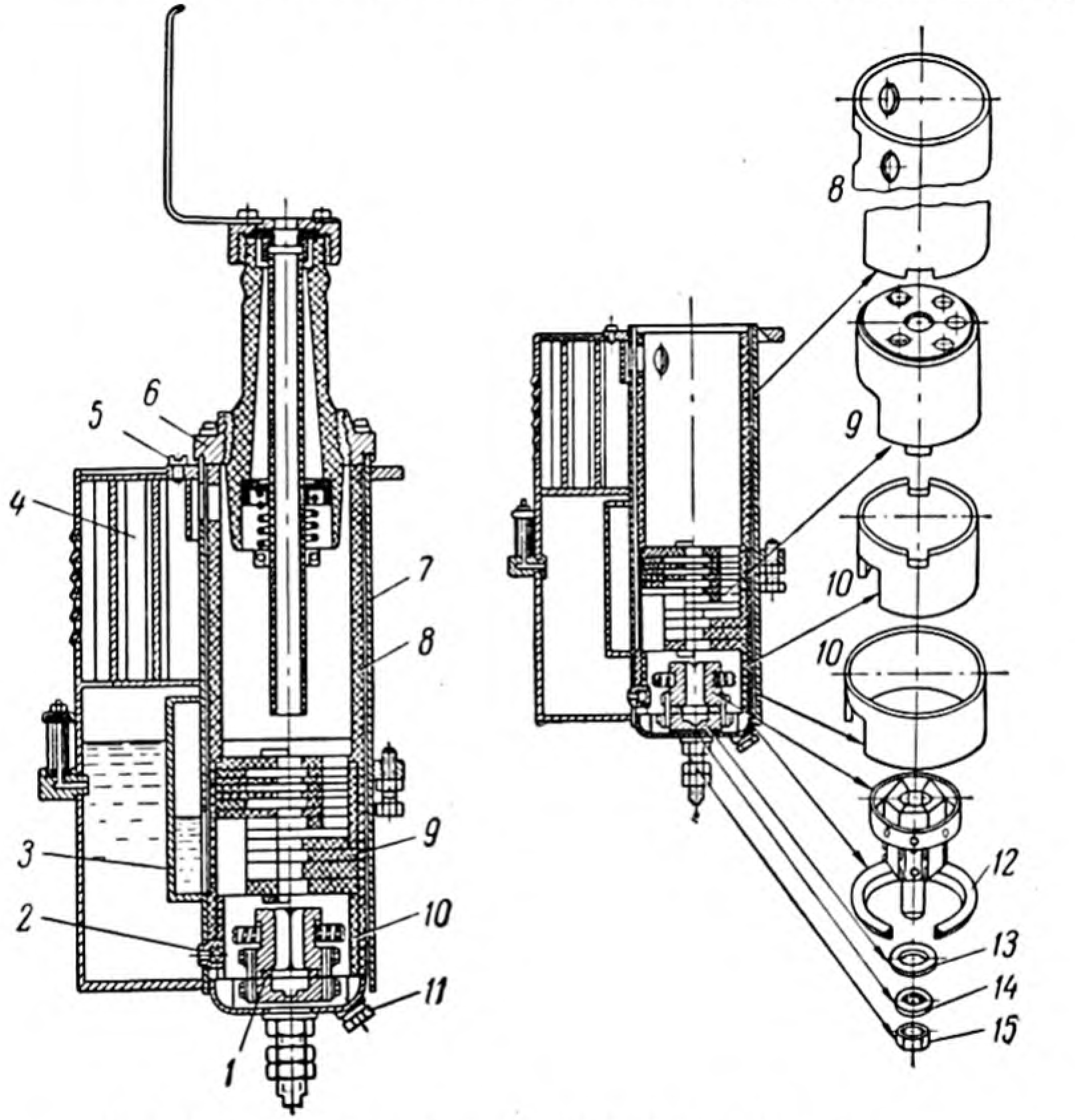


Fig. 71. Cross section through a ВМГ-133 breaker pole pot:

1—cluster contact; *2*—ball valve; *3*—steel chamber of baffle space; *4*—oil baffle; *5*—oil-filling hole plug; *6*—cover; *7*—steel cylinder; *8*—bakelised-paper distance sleeve; *9*—arc-control chamber; *10*—bakelised-paper support sleeve; *11*—oil drain hole and plug; *12*—plywood ring; *13*—cluster contact gasket; *14*—brass washer; *15*—brass nut

any one of the rods sinks into its cluster contact less, if at all, its insulator *15* is out of alignment. The latter should then be realigned.

The pots should be mounted on support insulators *3* bearing the same numbers (1 and 1; 2 and 2; 3 and 3). If the pots come separate-

ly from the frame, it is necessary to make sure that the serial numbers on the frame and the pots are the same. This is done in order that a given pot may be set in the same position as it was first assembled, adjusted and tested at the manufacturer's works.

The pots are next checked for verticality with a plumb-bob and for centre-to-centre spacing, which should be 250±5 mm. The pots are then clamped in place by bolts *4* (Fig. 74), and their contact rods *12* are linked to porcelain tie rods *11* (see Fig. 70).

A general view of a ВМГ-133 circuit breaker mounted in place is given in Fig. 75.

Coupling of the circuit breaker to a ПС-10 or ПРБА operating mechanism. The ВМГ-133 breaker is ordinarily operated by a ПС-10 solenoid-type mechanism (Fig. 76), weighing 45 kg and both are mounted concurrently.

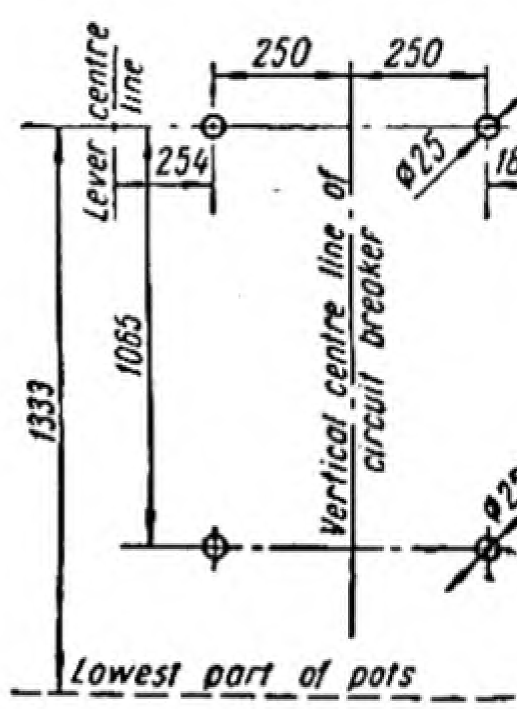


Fig. 72. Layout drawing for a ВМГ-133 breaker

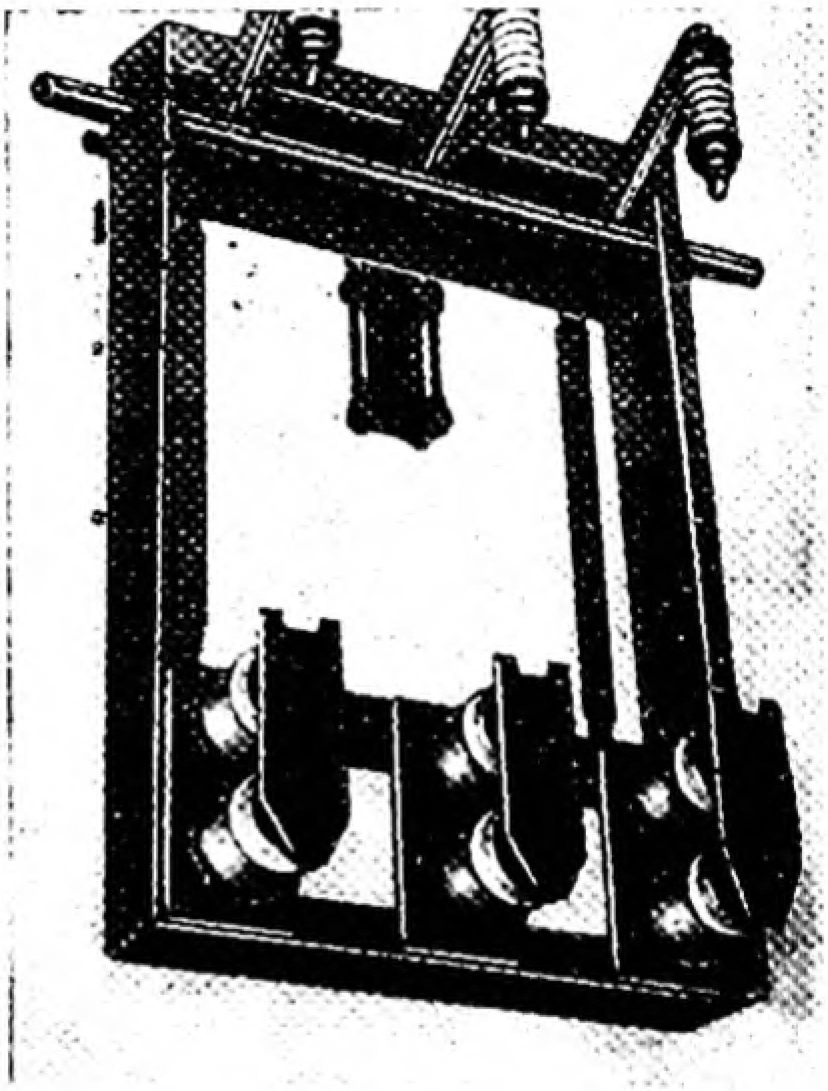


Fig. 73. Mounting of the ВМГ-133 breaker frame on a wall

The hole layout and mounting of the ПС-10 operating mechanism can be seen in Fig. 77.

After the circuit breaker and operating mechanism have been mounted, the shaft extension *6* (see Fig. 77) is fitted and an arm *2* is put on the breaker shaft. The operating mechanism is then set in the closed position and another arm *7* is seated on the shaft extension at an angle of 30 degrees from the vertical. Holes are then drilled and reamed in the shafts and their respective arms in the as-fitted position to lock the arms on the shafts with taper pins 60 mm long and 8 mm in dia.

Then the operating mechanism is put in the open position, and the arms on the two shafts are connected by the remote control tie rod.

In the above case the intermediate bearing *8* (see Fig. 77) is mounted on the breaker frame. However, it may be placed externally to the breaker, as shown in Fig. 78, in which case it is held in place by studs or bolts, depending on the material of the support.

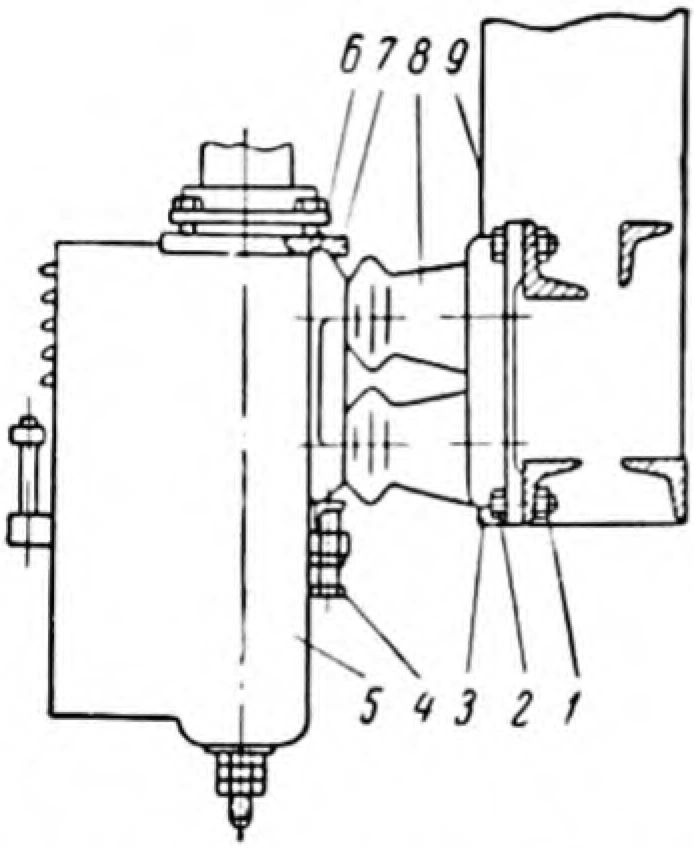


Fig. 74. Mounting of a pot on its support insulators:

1—nut; *2*—M12 bolt; *3*—base fitting; *4*—clamping bolt; *5*—pot; *6*—cap fitting; *7*—shoulder; *8*—doubled support insulators; *9*—breaker frame

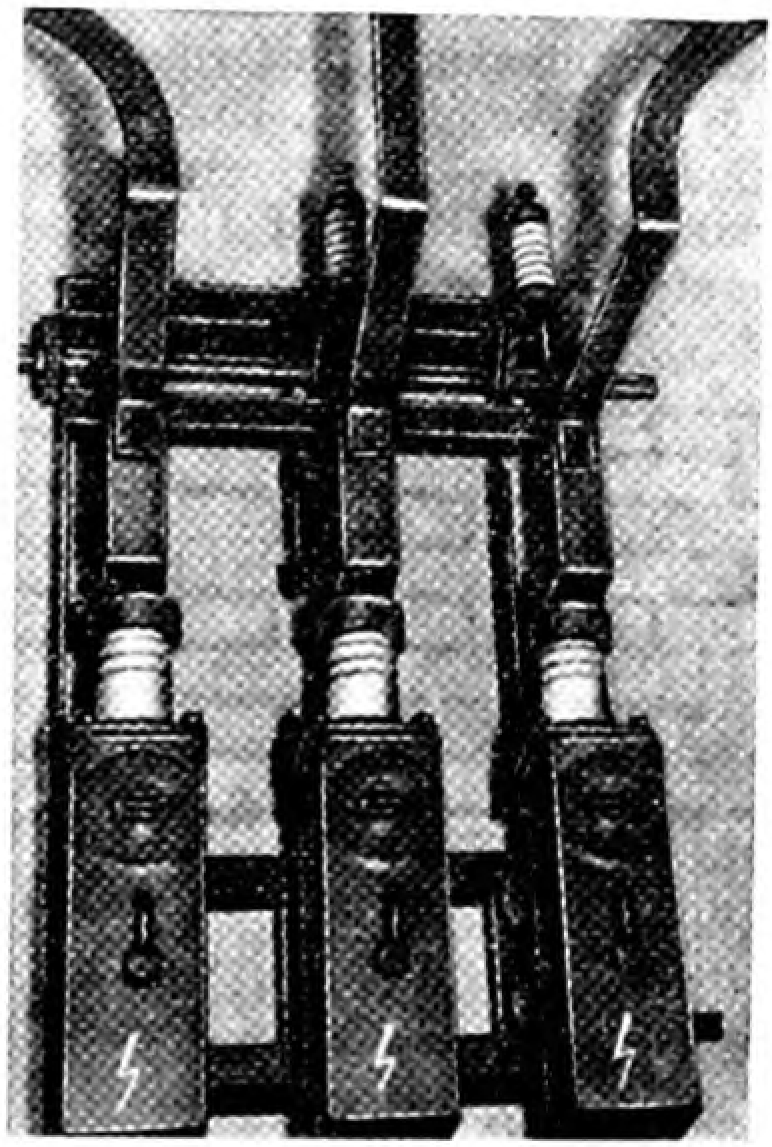
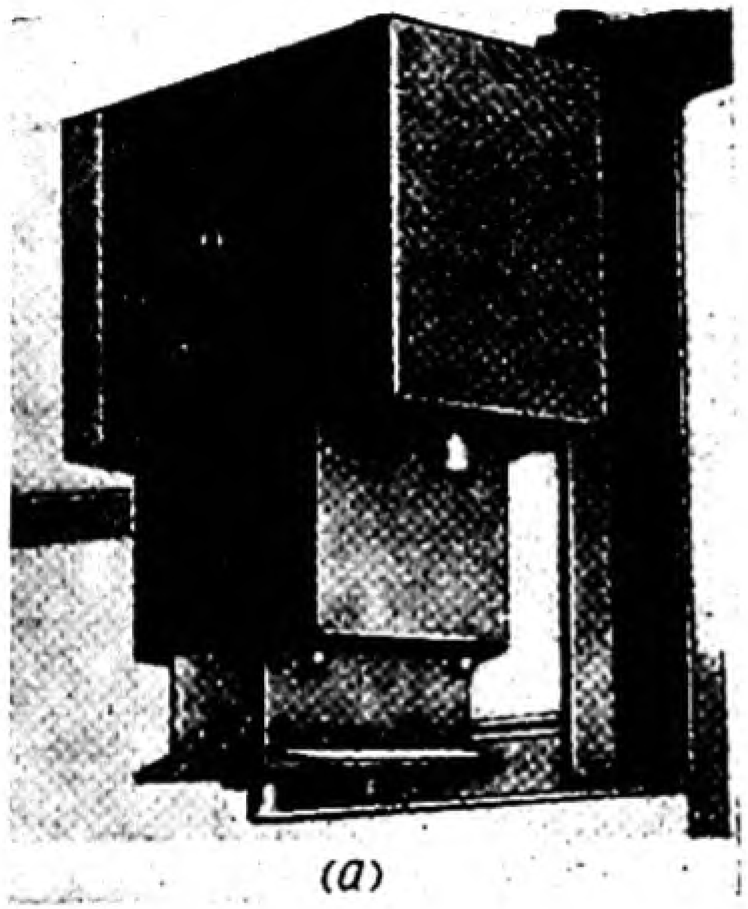


Fig. 75. General view of a mounted ВМГ-133 breaker

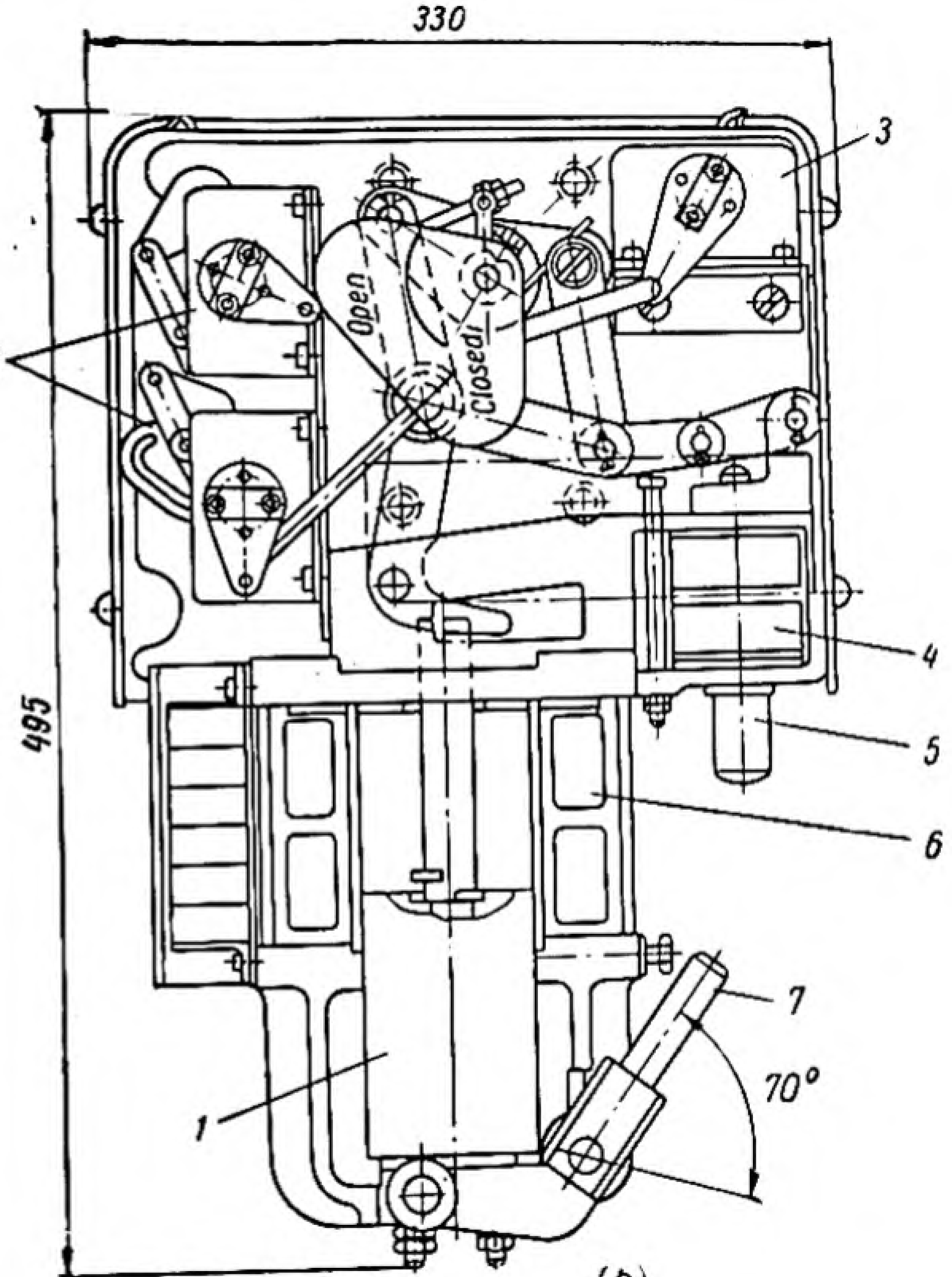
ВМГ-133 breakers may also be operated by a ПРБА lever-type mechanism provided with a semaphore position-indicator and capable of automatic tripping. This mechanism weighs from 25 to 27 kg.

Fig. 79 shows a ПРБА mechanism mounted for operation of a ВМГ-133 circuit breaker.

The linkage between the circuit breaker and the operating mechanism is installed when the latter is in the open position. The length of the rods *1* and *3* should be so adjusted that when the operating lever is turned all the way down in the open position the trip-free catch should engage the pivot pin of the latch. If it does so before the operating lever has moved all the way down, the tie rod *1* should be shortened. If, however, the lever reaches the stop without this



(a)



(b)

Fig. 76. ПС-10 solenoid operating mechanism:

a—general view; *b*—cross section: *1*—solenoid plunger; *2*—КСА auxiliary switch; *3*—КСУ auxiliary switch; *4*—opening coil; *5*—manual trip button; *6*—closing coil; *7*—lever for manual closing

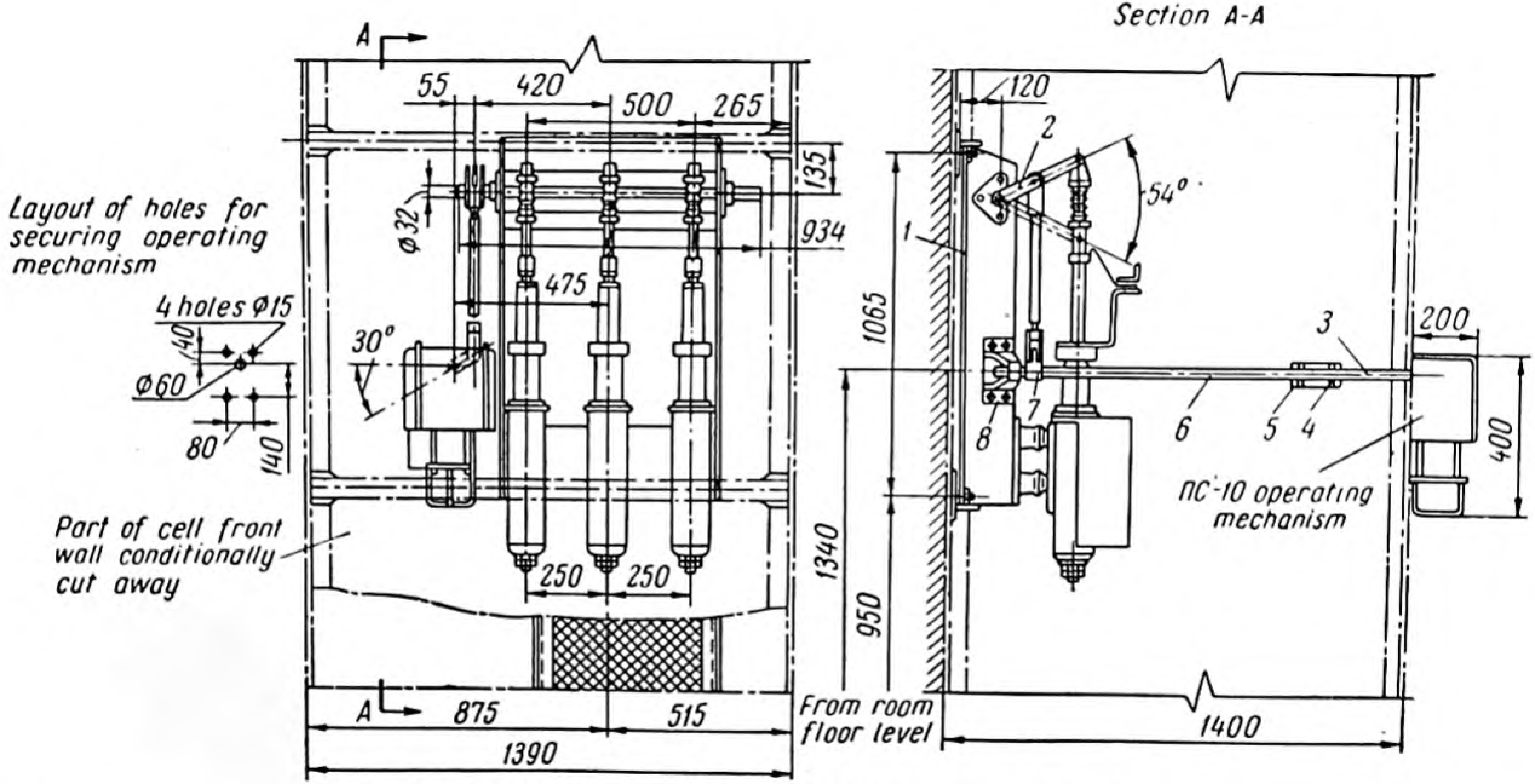


Fig. 77. ВМГ-133 breaker with a ПС-10 operating mechanism:

1—breaker frame; 2—breaker shaft arm; 3—operating mechanism shaft; 4—pins; 5—coupling sleeve; 6—extension shaft; 7—arm; 8—intermediate bearing

engagement taking place, the tie rod must be lengthened. When the operating mechanism is in the closed position, the circuit breaker should also be in the fully closed position.

If the circuit breaker turns out to be incompletely closed, the tie rod *3* must be shortened. If, however, the circuit breaker fully closes before the operating handle has moved all the way up, the tie rod must be lengthened.

Still another mechanism used to operate ВМГ-133 breakers is the УПГП universal spring-weight loaded type weighing 80 kg.

This operating mechanism may be mounted either on a masonry wall or a metal framework of sufficient rigidity. When wall mounted, these mechanisms are secured by means of M16 through bolts having a length of $l+50$ mm, where l is wall thickness, and are passed through 50×50 mm steel angles on the other side of the wall for greater rigidity.

The shafts of a ВМГ-133 breaker and УПГП operating mechanism are connected by a linkage as shown in Fig. 80.

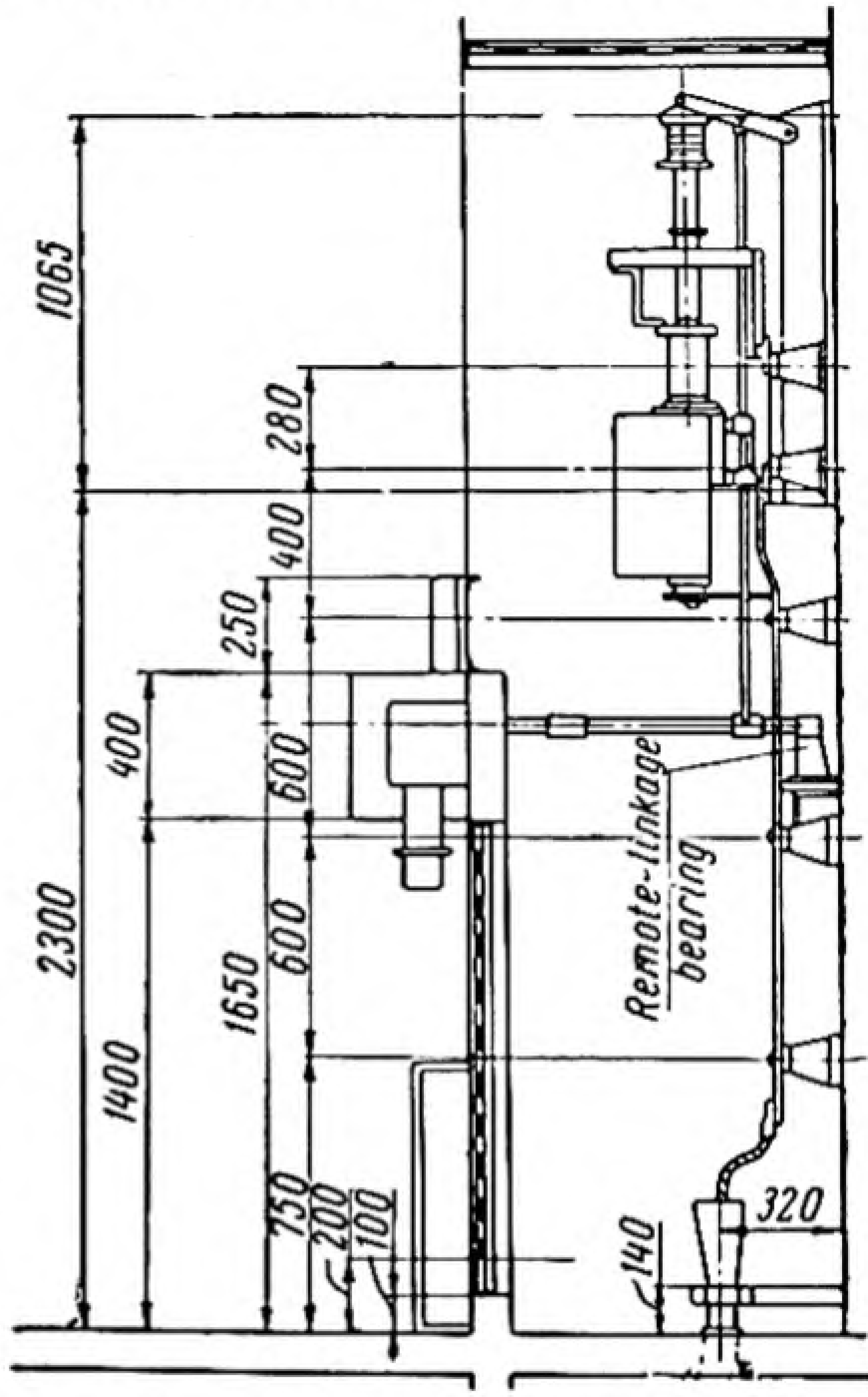


Fig. 78. Another method of mounting a ВМГ-133 breaker with a ПС-10 operating mechanism (intermediate bearing separately mounted)

Adjustment of a circuit breaker and its operating mechanism for joint operation. After a circuit breaker has been coupled with its operating mechanism, they are given final adjustment for joint operation. This involves adjustment of contact rod travel to within 250 ± 5 mm. In the open position the middle lever on the circuit breaker should bear upon the oil dashpot striker head (Fig. 82), while in the closed position it should bear on the spring buffer bolt head (Fig. 81) so that the spring is compressed 14 ± 1 mm.

The clearance between the spring buffer washer and buffer housing in the closed position should be anywhere from 0.5 to 1.5 mm. If the clearance is less than 0.5 mm, the contact rods on a closing stroke may be stopped too early. If the gap is greater than 1.5 mm,

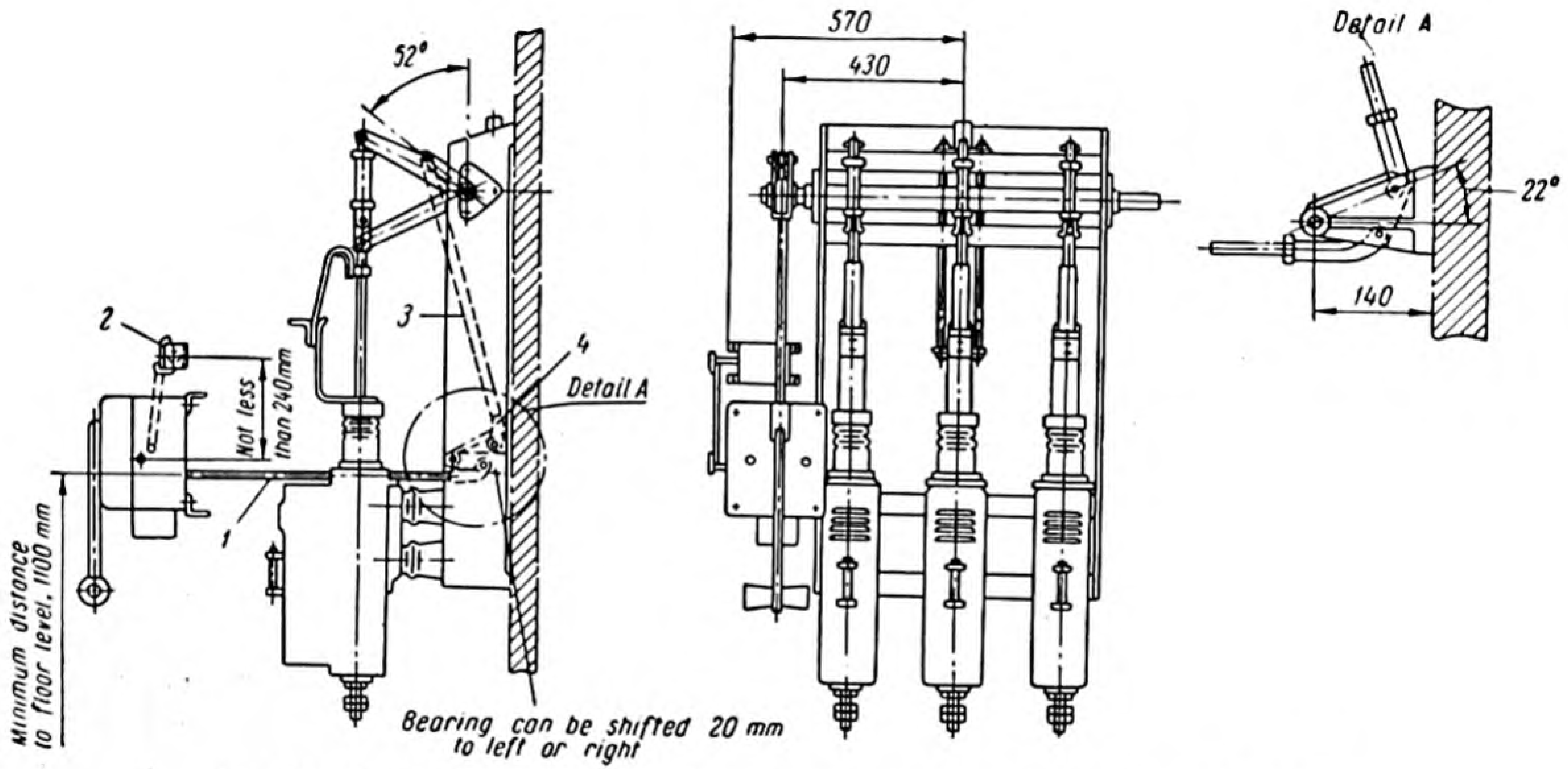


Fig. 79. **Mounting of a ВМГ-133 breaker for operation by a ПРБА mechanism:**
1—horizontal tie rod; 2—КСА auxiliary switch; 3—vertical tie rod; 4—intermediate bearing

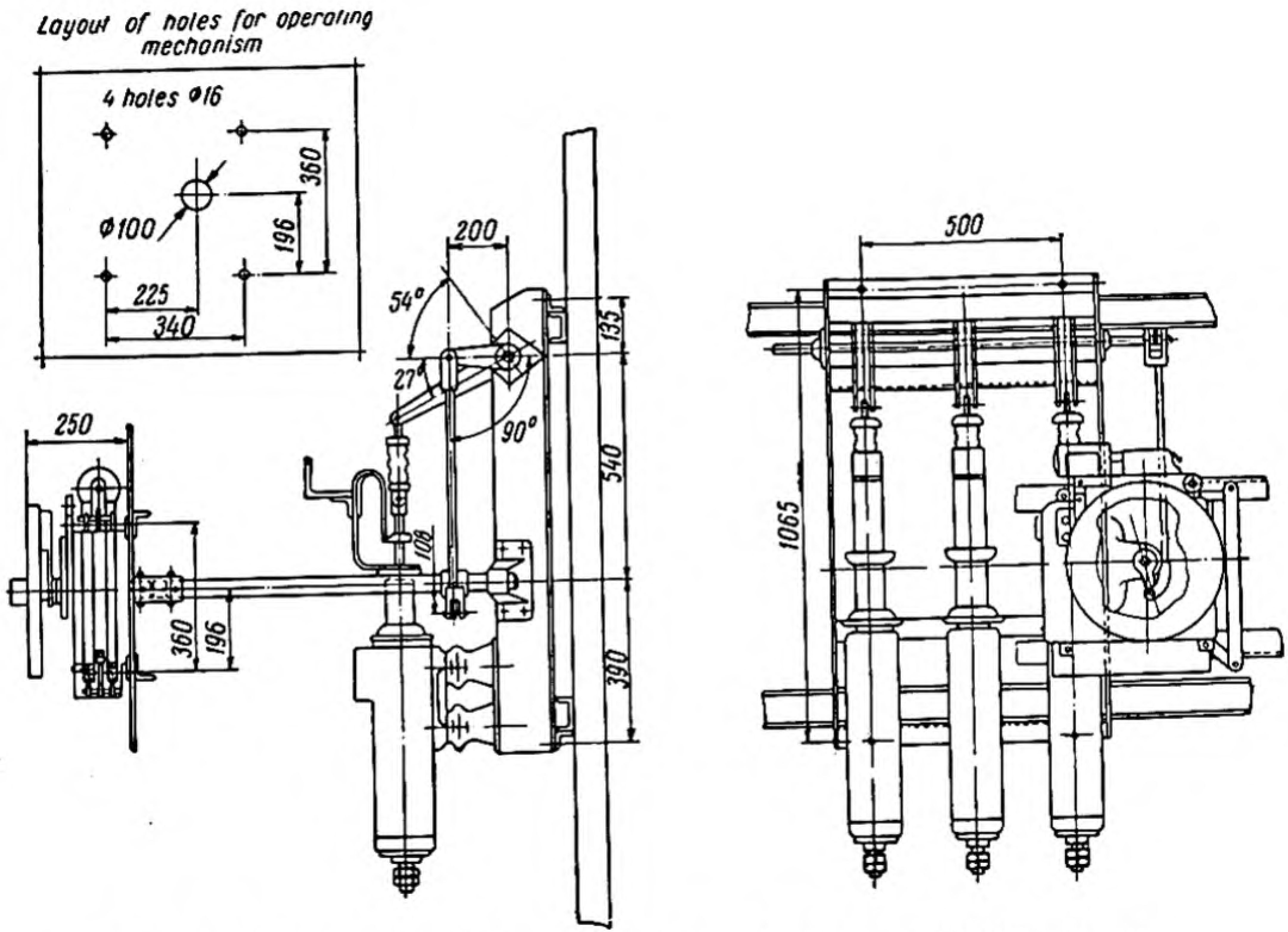


Fig. 80. Mounting of a ВМГ-133 breaker for operation by a type УПГП mechanism

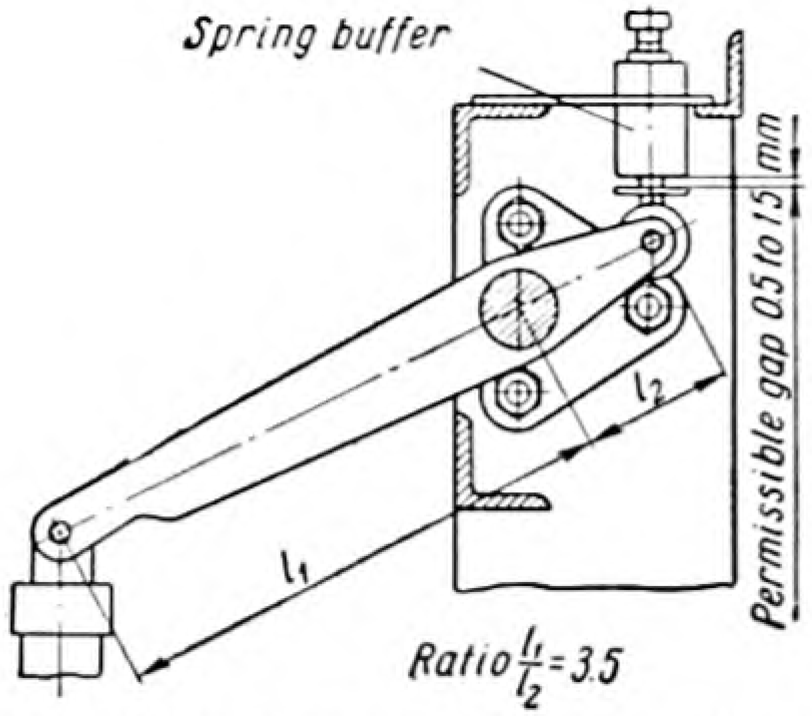


Fig. 81. Position of middle lever when breaker is closed (lever end bears on spring-buffer bolt head)

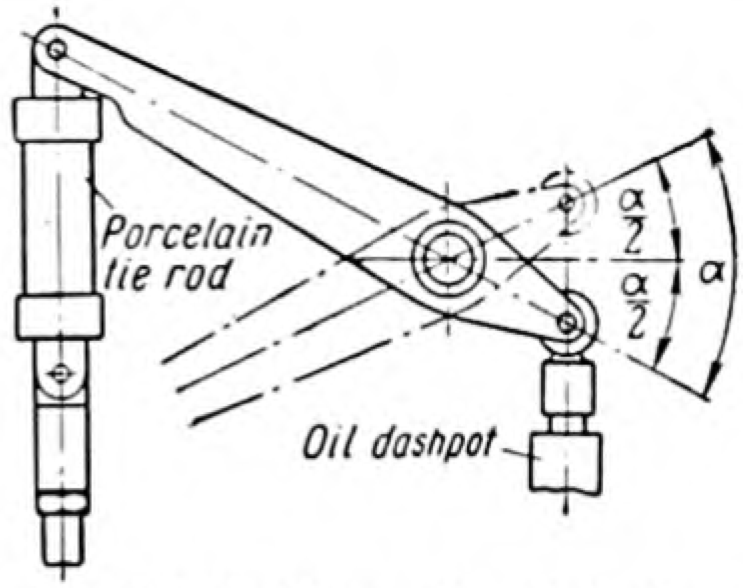


Fig. 82. Position of middle lever when breaker is open (lever end bears on oil dashpot striker head)

the contact rods may go too deep into their cluster contacts, causing a severe shock to the circuit breaker and even breaking the support insulators and porcelain tie rods.

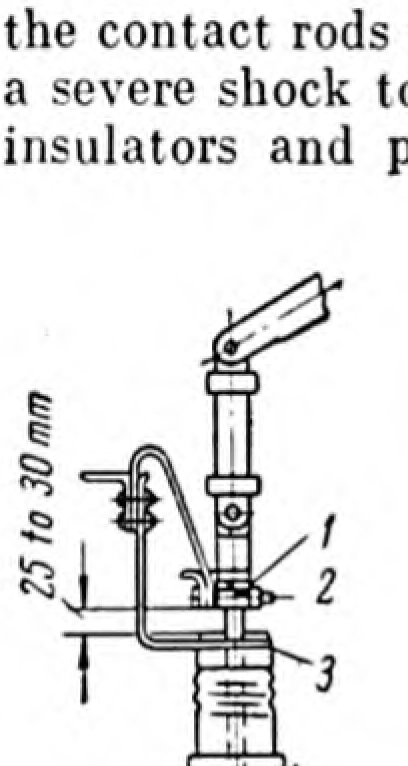


Fig. 83. Measuring of the overtravel gap for the contact rod:

1—adapter; *2*—connecting block; *3*—head of porcelain bushing cap bolt

The gap can be reduced by placing washers between the bolt head and the buffer washer.

In the closed position of the circuit breaker the distance between the end of a contact rod and the base of its cluster-contact should be anywhere from 25 to 30 mm. Provision of this distance, which may be called the overtravel gap, prevents the rods from moving past the limiting position.

To check the overtravel gap, the circuit breaker is set in the closed position, the contact rod is detached from the porcelain tie rod and lowered until it is abutting with the base of the cluster contact. A mark is drawn with a pencil on the rod level with the porcelain bushing. The contact rod is then lifted and attached to the porcelain tie rod, and another mark is drawn in this position. The distance between the marks will give the overtravel gap.

When necessary, the overtravel gap can be adjusted by means of the adapter *1* on the contact rod (Fig. 83). As the cluster contact is 70 mm high and the overtravel gap is 25 to 30 mm, the contact rod should move 40 to 45 mm into the cluster contact.

A distance equal to the overtravel gap should be maintained between the block *2* receiving the flexible connection, and the bolt heads *3* on the bushing cap.

The circuit-breaker frame should be connected to the earthing system.

In conclusion the threaded fastenings should be checked to see that they are fully tightened and locked, the oil in the circuit-breaker pots checked for proper level in the oil gauges, and the rubbing parts of the circuit breaker, operating mechanism and linkage lubricated with petroleum jelly or a nonfreezing grease. A thin coat of petroleum jelly should also be applied to the contact rod. Then the circuit breaker should be examined for proper adjustment and the control circuits checked for completed connections and proper voltage.

After ten trial closings and openings, and final inspection of the circuit breaker and its operating mechanism, the apparatus may be turned over for service.

Problem. Write up an operation sequence for mounting a ВМГ-133-II circuit breaker according to Fig. 78.

15. Mounting of МГГ-10 Oil Circuit Breakers

The МГГ-10 is a generator oil circuit breaker intended for use in circuits with heavy (generator) currents at voltages up to 10 kv. It is designed for indoor installation in dry, heated and unheated locations. These circuit breakers are available in current ratings of 2,000 and 3,000 amperes.

A general view and the main dimensions can be seen in Fig. 84. The dry weight of a МГГ-10 breaker is 580 to 600 kg, and its six pots take 20 kg of oil.

МГГ-10 breakers are operated by a ПЭ-2 solenoid mechanism weighing 173 kg. A general view, the construction, and overall dimensions of the latter are given in Fig. 85.

Visual inspection. Once on the erection site, the circuit breaker, still in its packing crate, should be immediately taken into a dry room, checked for damage to the packing crate, unpacked, taking care to avoid any injury to the contents, and examined for breakage caused during transportation. At the same time the contents are checked against the packing list for missing parts.

If visual inspection reveals moisture on the outer surfaces, the bakelised sleeves of the pots and the arc-control chambers must be examined thoroughly. If these parts are found to be moist, they must be allowed to dry in an oven at 80° to 90°C for 48 hours, or kept

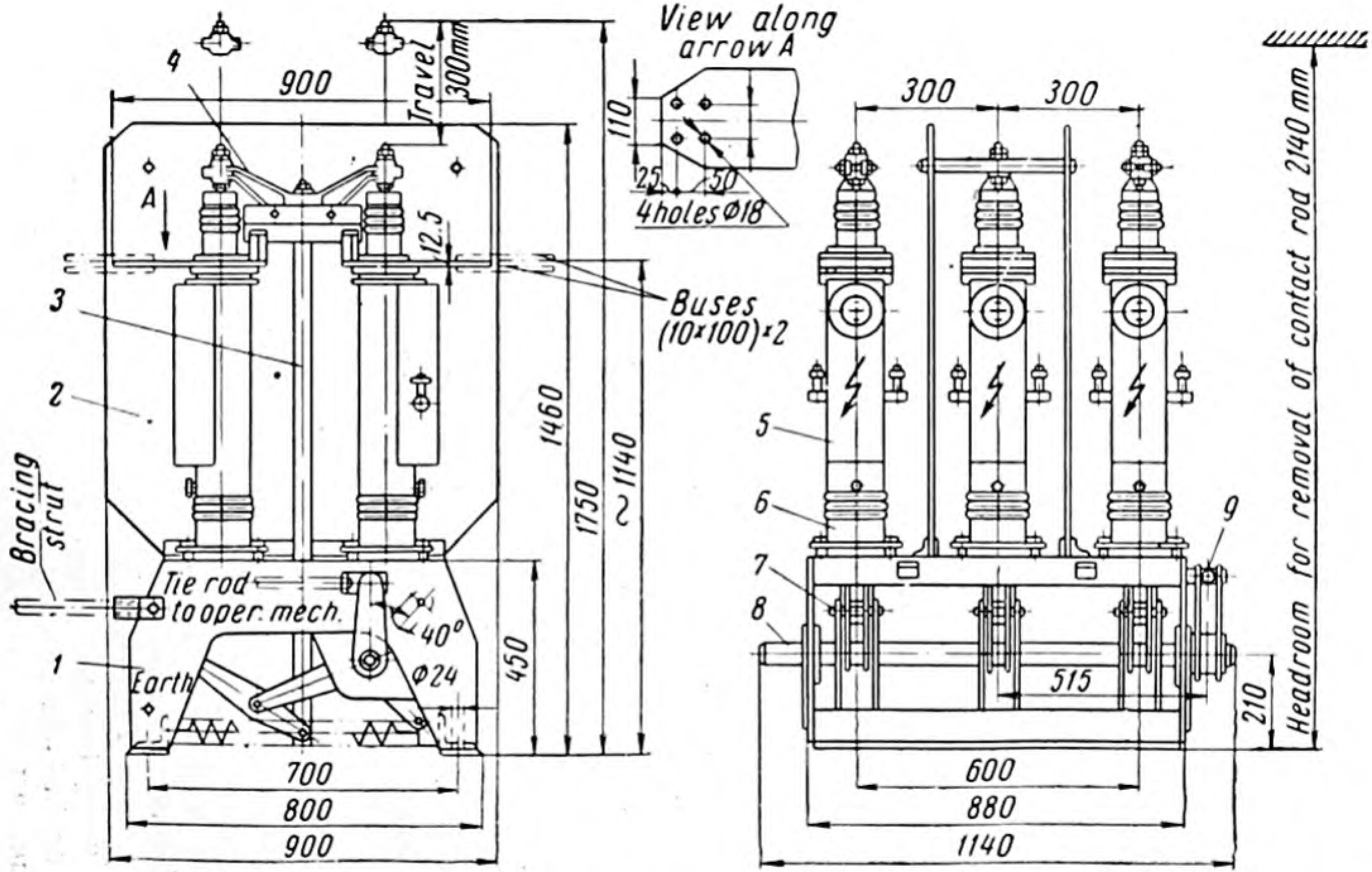


Fig. 84. **General view and main dimensions of a МГГ-10 oil circuit breaker:**

1—frame; 2—insulating barriers; 3—insulating lift rod; 4—silumin cross-head carrying the moving contacts; 5—pot cylinder; 6—support insulator; 7—operating mechanism; 8—shaft; 9—linkage

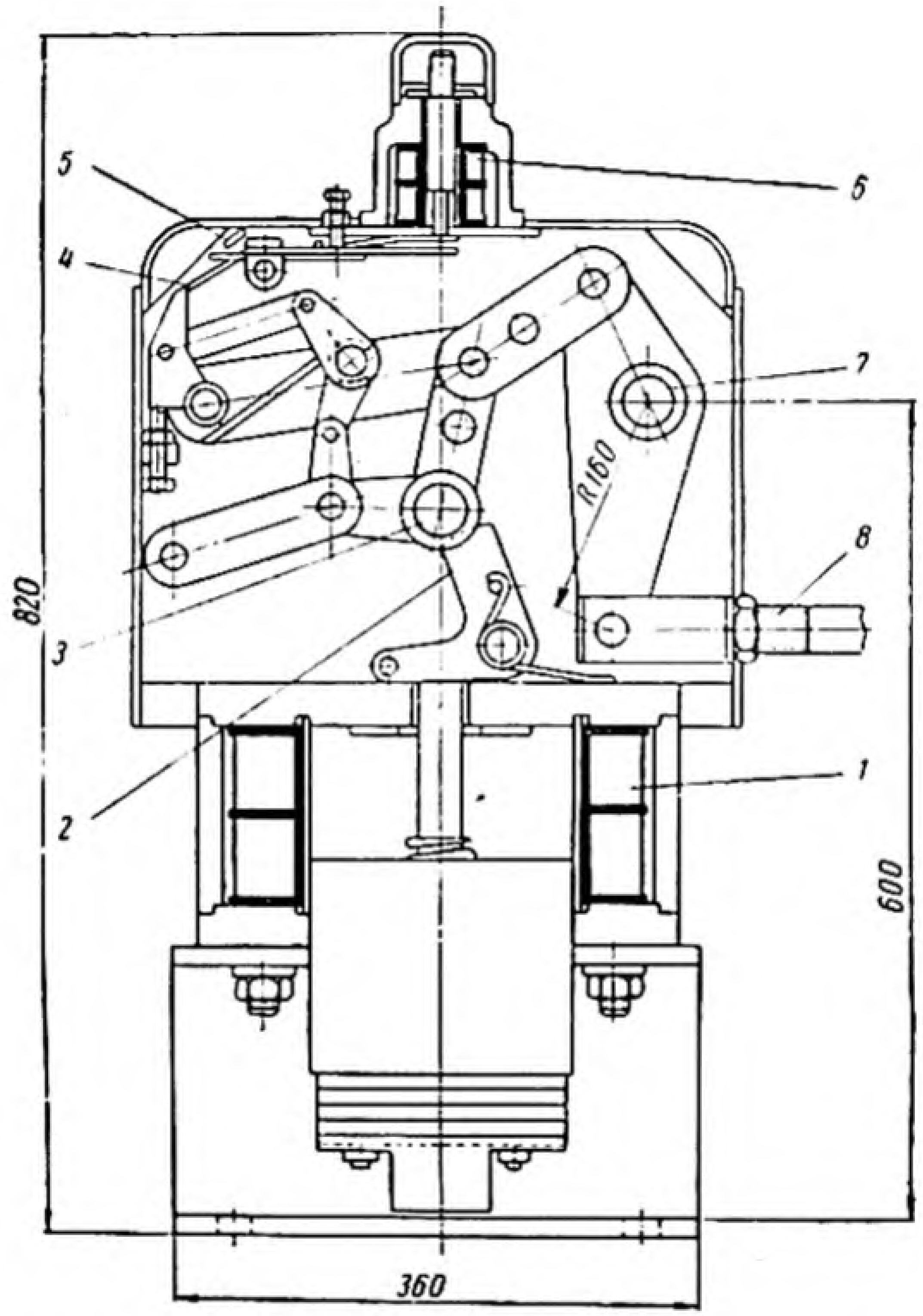


Fig 85. ПЭ-2 solenoid operating mechanism (in closed position):

1—closing coil; *2*—latch; *3*—roller shaft; *4*—trip-free mechanism; *5*—safety bolt plate; *6*—opening coil; *7*—shaft; *8*—tie rod to breaker

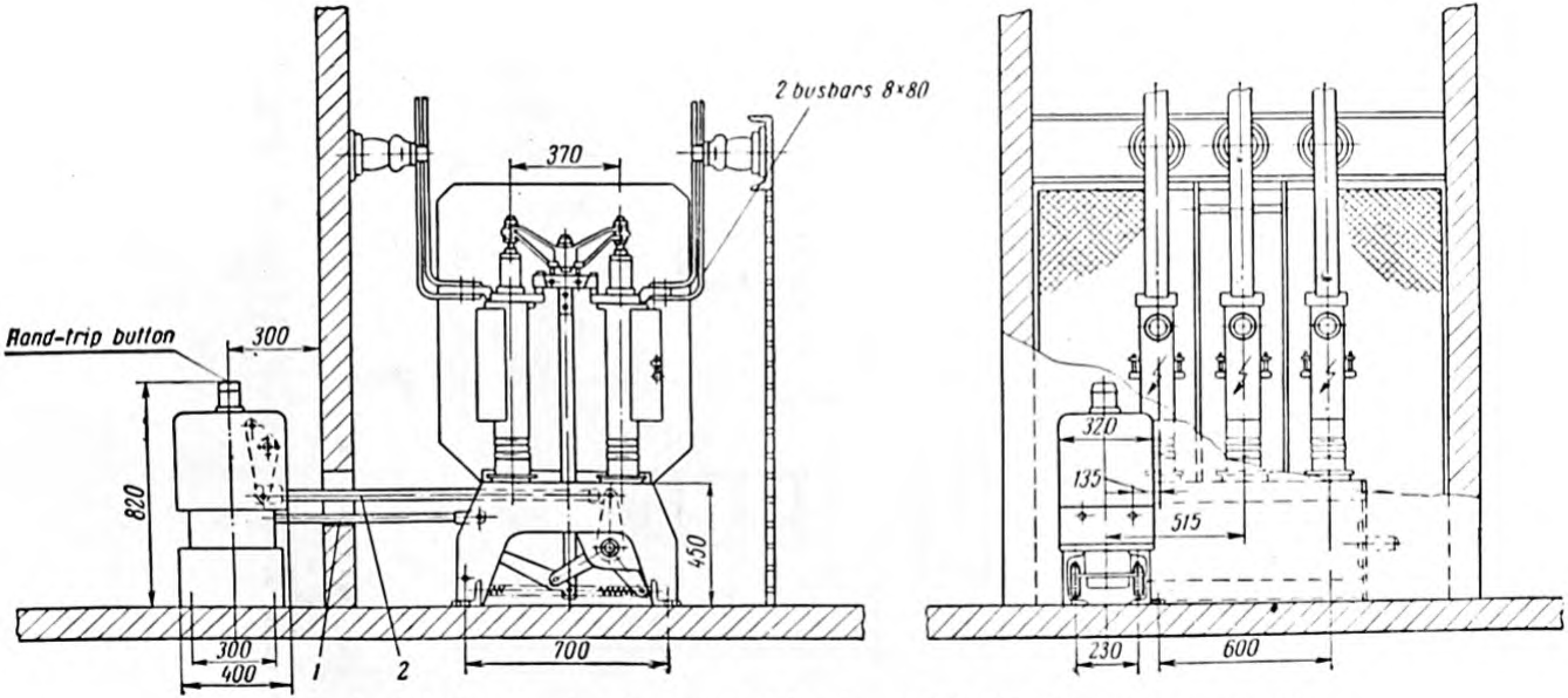


Fig. 86. Installation drawing for a МГГ-10 breaker and its ПЭ-2 operating mechanism:
1—strut; 2—pipe tie rod

submerged in dry transformer oil at 70° to 80°C for the same interval of time.

Mounting of the circuit breaker and operating mechanism. The circuit breaker should be mounted on the floor of the switchgear cell or on a special foundation prepared by the builders. The bolt holes for the circuit breaker and its operating mechanism should also be provided by the builders to a layout drawing made on the basis of the installation drawings (Fig. 86).

The circuit breaker is pulled to its cell on a truck or on rollers by a hand-operated or electric winch.

The circuit breaker must be put in its permanent position to the installation drawing so that the four holes in its frame are opposite the holes left in the floor or foundation. M20 anchor bolts are then passed through the holes for the builders to grout them in. Before the circuit breaker is finally bolted down, boiler-steel pads 8 to 10 mm thick are placed under the breaker frame to protect the concrete from crumbling due to the shock loads when the circuit breaker is closed or opened.

The operating mechanism is mounted concurrently with the circuit breaker and is clamped in place with M20 bolts on a concrete slab or steel channels set up in advance.

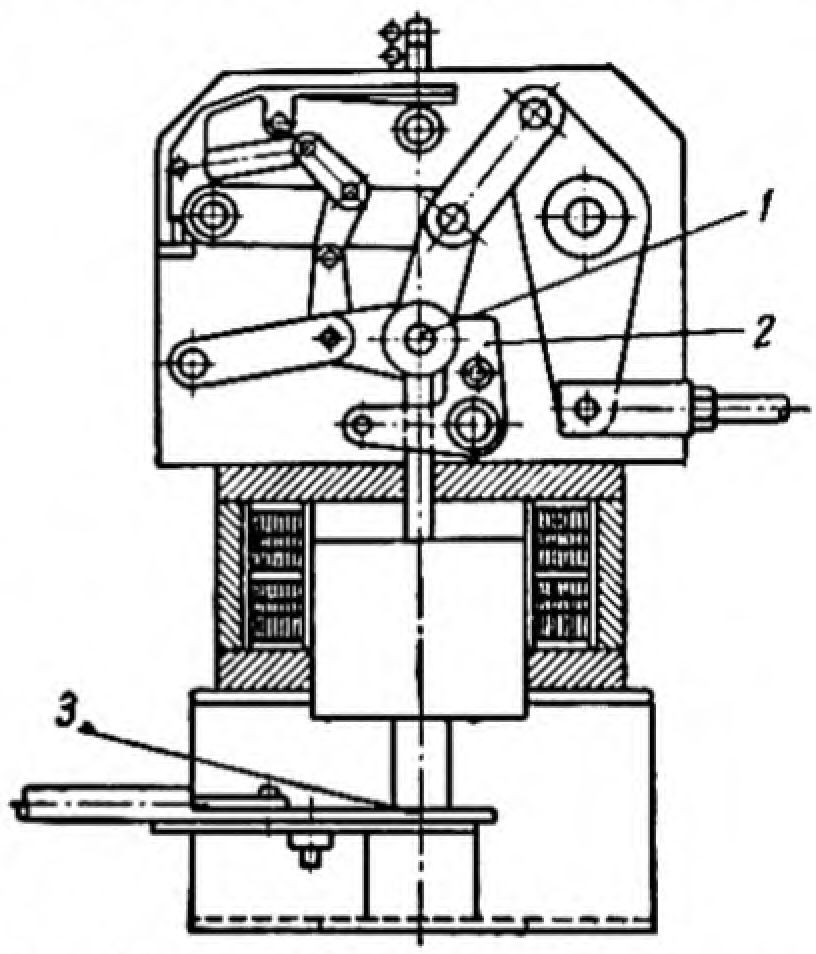


Fig. 87. Operating mechanism in process of being pushed past the closed position:
1—roller shaft; *2*—hold-in latch; *3*—jack

The circuit breaker and its operating mechanism must be so positioned relative to each other that their operating levers linked by a common tie rod are in the same plane. The circuit-breaker frame should be levelled and plumbed before the nuts may be screwed onto the anchor bolts, and the bracing strut (see Fig. 86) may be installed between the circuit breaker and the operating mechanism.

Take-down inspection. In the process of installation, the circuit breaker is usually given a take-down inspection during which the crossheads are removed, the arcing rods are pulled out, and the pots are taken apart. First the latch which holds the breaker in the closed position is released. Before this can be done, the operating mechanism should be pushed past the closed position by hand so that the roller shaft *1* (Fig. 87) stops slightly beyond the hold-in latch *2*; the tie

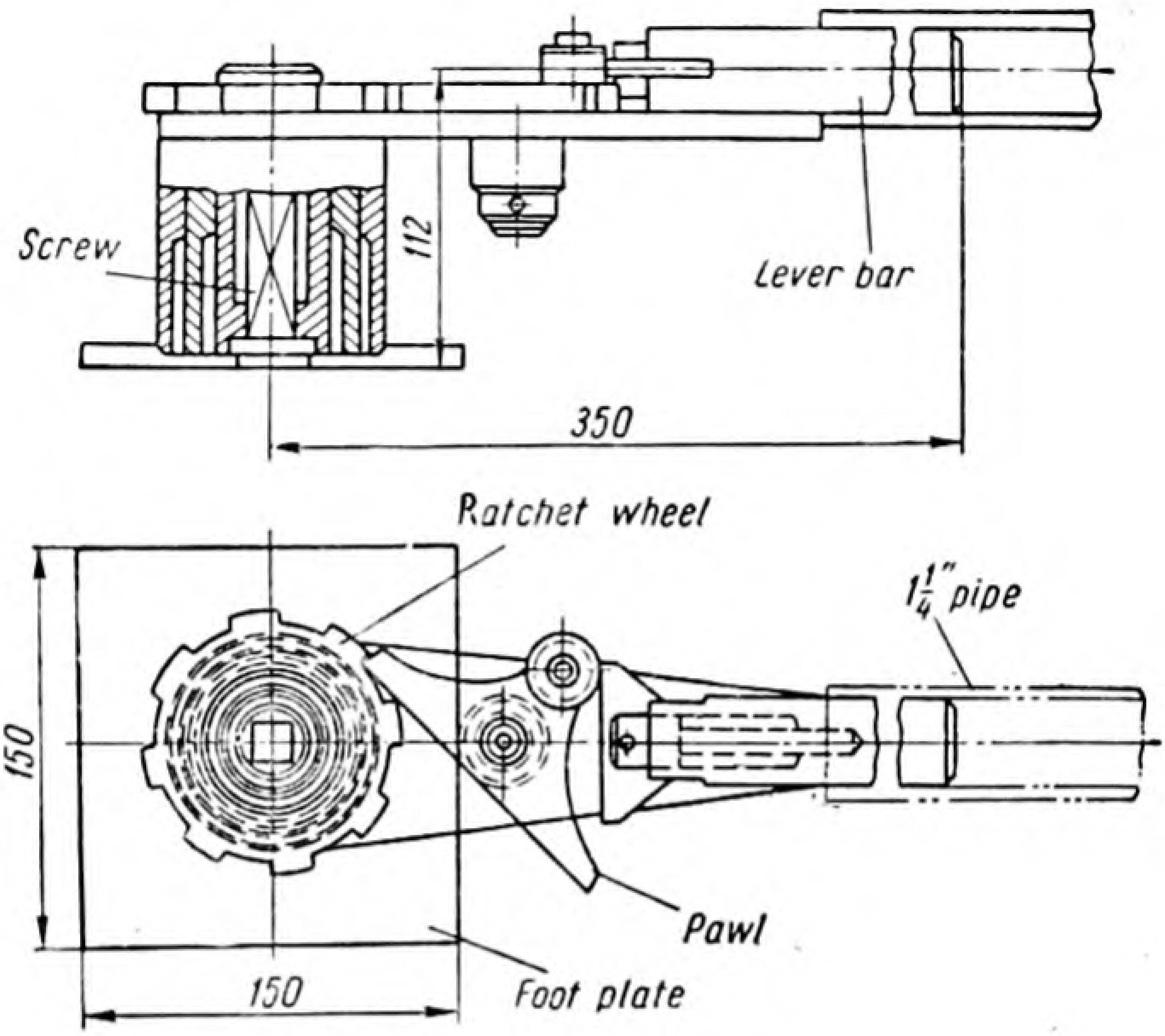


Fig. 88. Jack

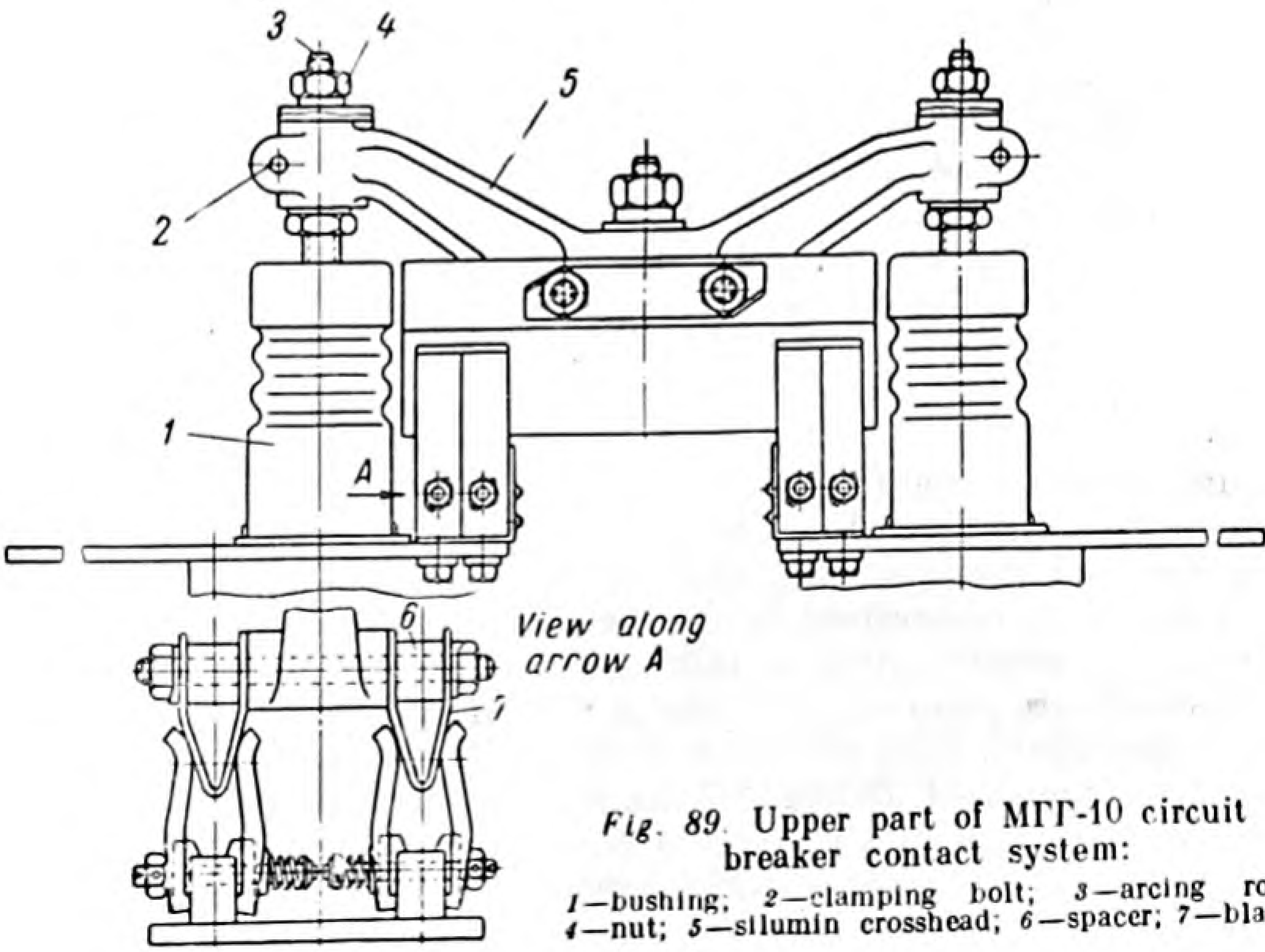


Fig. 89. Upper part of МГГ-10 circuit breaker contact system:

1—bushing; 2—clamping bolt; 3—arcing rod; 4—nut; 5—silumin crosshead; 6—spacer; 7—blade

rod is connected between the circuit breaker and operating mechanism; and the circuit breaker is now made to go past the closed position to release the temporary shackle, which is then taken off and the circuit breaker is slowly opened as far as it will go.

For the purpose of erection and adjustment the circuit breaker can be closed and opened by means of a jacking device *3*. The jack is placed under the lower end of the operating mechanism plunger, its pawl (Fig. 88) is placed in the required position, and the jack lever is swung from right to left and back. For ease of operation, a $1\frac{1}{4}$-inch pipe, 1 to 1.5 metres long, can be slipped on its lever.

After the circuit breaker has been opened, it is partially dismantled in order that some of its parts can be inspected. First the nut *4* (Fig. 89) is unscrewed and the clamping bolts *2* which hold the arcing rods *3* in the silumin crosshead *5* are slackened. The arcing rods are then allowed to enter their fixed cluster contacts *4* as far as they will go (Fig. 90). Next the insulating rods *3* (see Fig. 84) are detached from the breaker mechanism (Fig. 91) and removed together with the crossheads. Following this, the arcing rods are taken out and the pots are dismantled.

Disassembly and re-assembly of the pots. The covers *13* and their bushings (see Fig. 90) are removed first, followed by the bakelised sleeves *1* and arc-control chambers *2* (Fig. 92).

The cluster contacts are inspected visually and by touch, without removing them from the pots. For visual inspection, a 12-volt lamp should be lowered into the pot. If there is doubt as to the condition of the cluster contact, it ought to be taken out with a special key (Fig. 93) furnished with the breaker by the manufacturer.

The internal surfaces of the pots should be rinsed with pure transformer oil. At the same time the pots for the oil gauge *10* and valve *8* should be checked to see that they are not clogged (Fig. 90). This is done by pouring

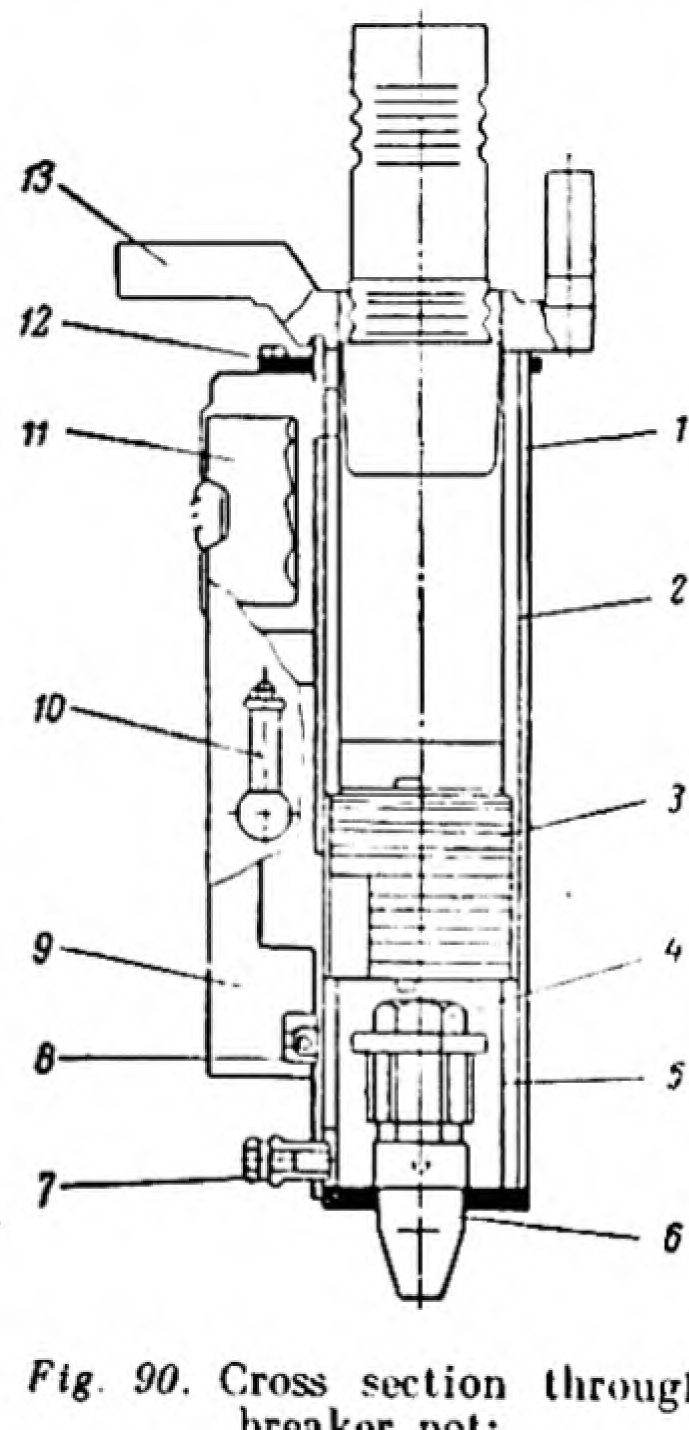


Fig. 90. Cross section through breaker pot:

1—steel cylinder; *2*—upper bakelised-paper sleeve; *3*—arc-control chamber; *4*—cluster contact; *5*—lower bakelised-paper sleeve; *6*—boss of cluster contact; *7*—oil drain plug; *8*—ball valve; *9*—reservoir; *10*—oil gauge; *11*—oil baffle; *12*—oil-filling hole and plug; *13*—cover and bushing

transformer oil into the pots through the oil filler *12* and by checking the oil level in the oil gauge and in the pot. If the oil level is the same in both, the oil gauge and valve are in good condition.

The insulating parts taken out of the pots and also the porcelain insulators are wiped with clean dry lint-free rags.

If all the parts taken out of a pot are good, they may be re-assembled in a reverse order.

When replacing a cluster contact (if it has been removed from its pot), it should be examined to make sure that the tinned end of the boss *6* is clean (see Fig. 90).

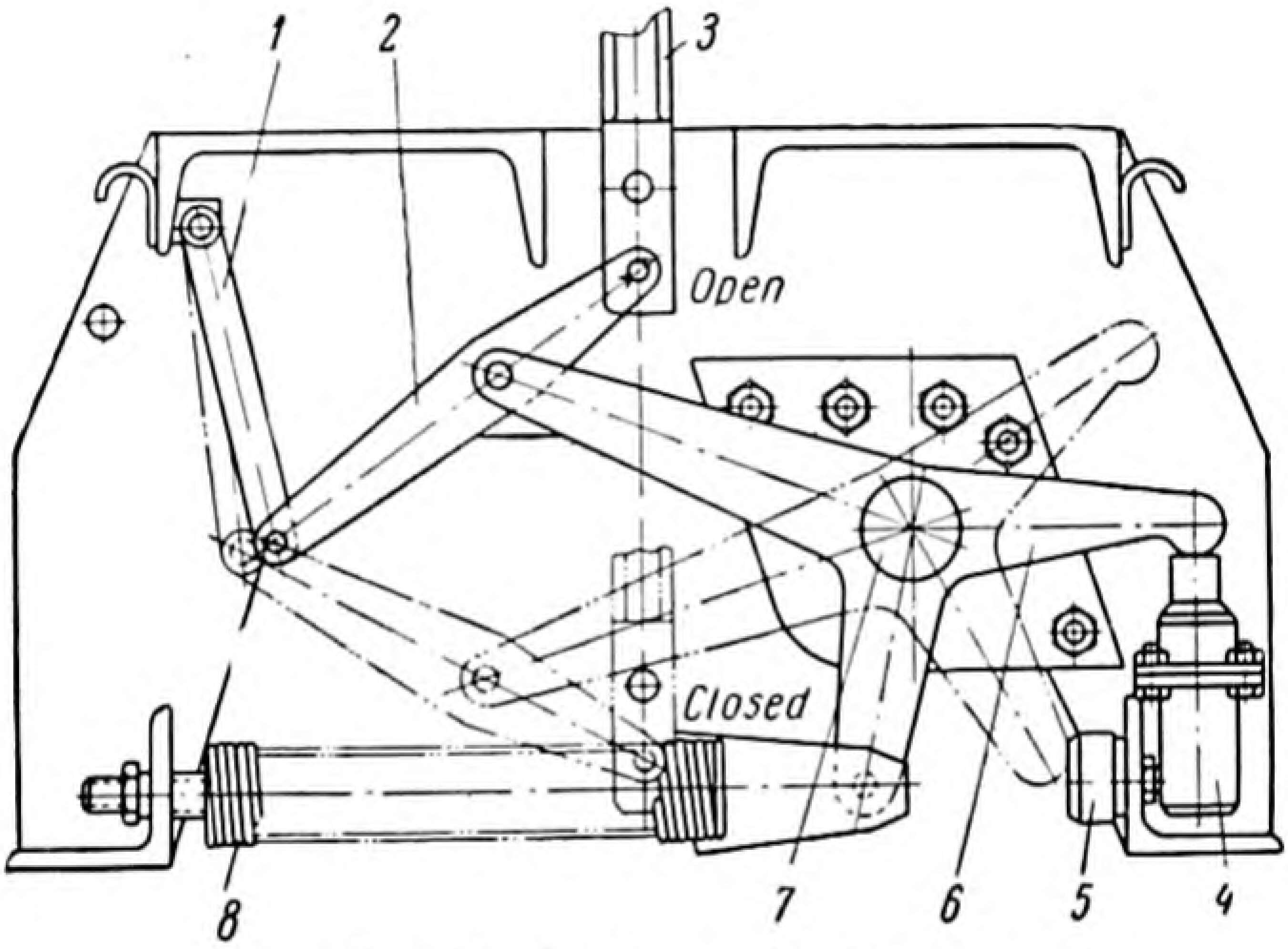


Fig. 91. Breaker mechanism:

1—hanger link; *2*—rocking lever; *3*—insulating lift rod; *4*—oil dashpot; *5*—stop for closed position; *6*—three-arm lever; *7*—shaft; *8*—opening springs

When the arc-control chamber is put back in place, a gap of 10 to 15 mm (distance D in Fig. 94) should be provided between the bottom surface and the top of the cluster contact.

For this, the height of the arc-control chamber (dimension B) is measured first and then the distance from the cluster-contact fingers to the upper edge of the pot (dimension A) is taken with a steel scale. After the arc-control chamber has been inserted in the pot, the distance between the top of the chamber and the top of the pot (dimension C) is measured.

The distance from the chamber to the cluster contact (dimension D) can now be determined as the difference of the measured distances, i.e.,

$$D = A - (B + C).$$

If dimension D happens to be other than 10 to 15 mm, the mounted height of the chamber within the pot (dimension C) should be changed accordingly by inserting pressboard rings under the lower bakelised sleeve *3* (see Fig. 92), or by reducing its height.

The holes in the upper bakelised sleeve *1* should coincide with those in the steel cylinder.

Care must be taken that the tinned ends of the pots are clean when the covers and their bushings are put on. Their bolts must be tightened uniformly to avoid misalignment. At the same time the arcing rods should be checked to see that they are free to move, without binding or excessive friction. This is done by releasing the arcing rod from a height of about 500 mm (the distance from rod top to bushing top). The arcing rods should sink 100 mm into their cluster contacts by gravity alone.

The next step is to check the pots for correct positioning and mounting. Their verticality is checked with a plumb-bob, and their spacing with a folding rule

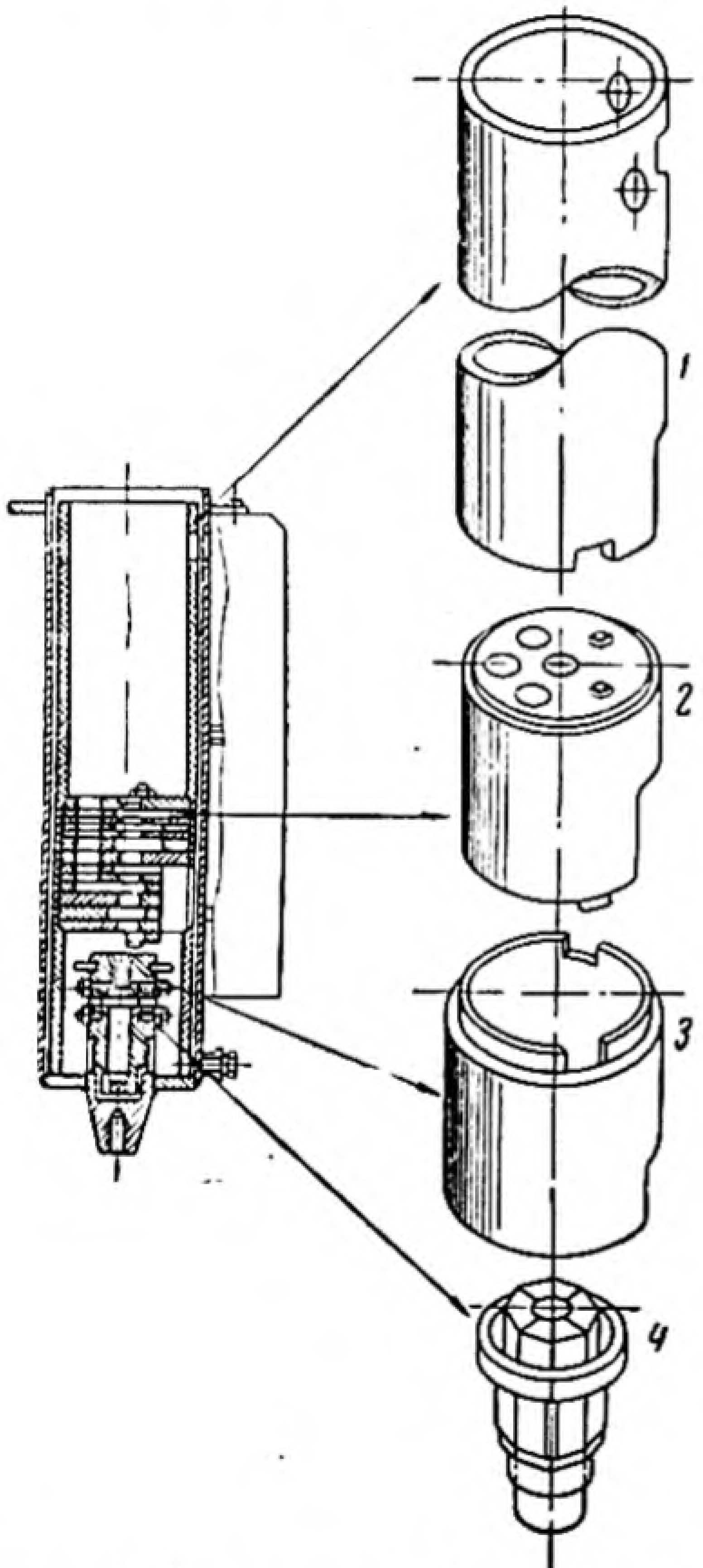


Fig. 92. **Arrangement of parts in the pot:**

1—upper bakelised-paper sleeve; *2*—arc-control chamber; *3*—lower bakelised-paper sleeve; *4*—cluster contact

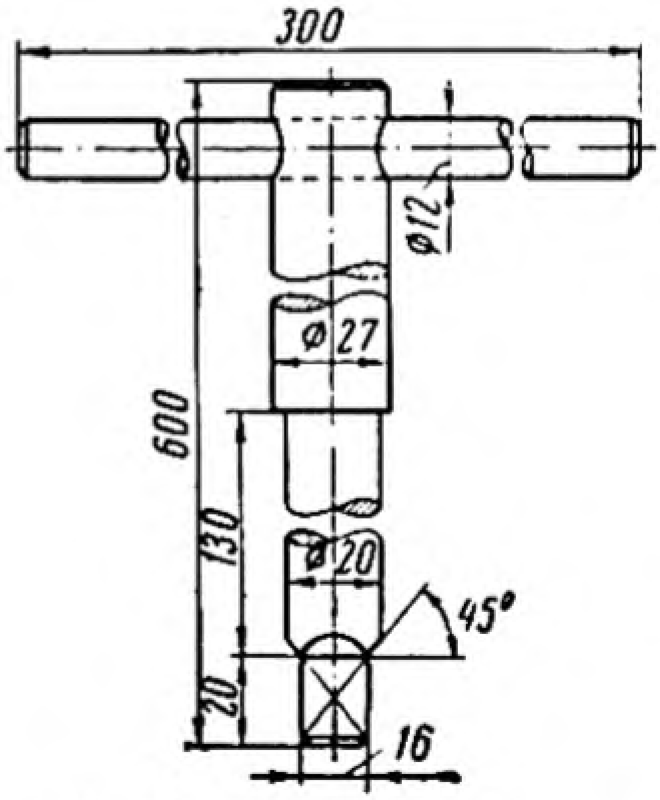


Fig. 93. **Key used for removing a cluster contact**

or a scale. The centre-to-centre distance between the pots of a phase should be 370 mm, and between the pots of two adjacent phases 300 mm. At the same time the operating contacts of the pots of each phase are checked for alignment.

The pots of each phase should also be checked for their position relative to the rocking lever 2 of the breaker linkage (Fig. 91).

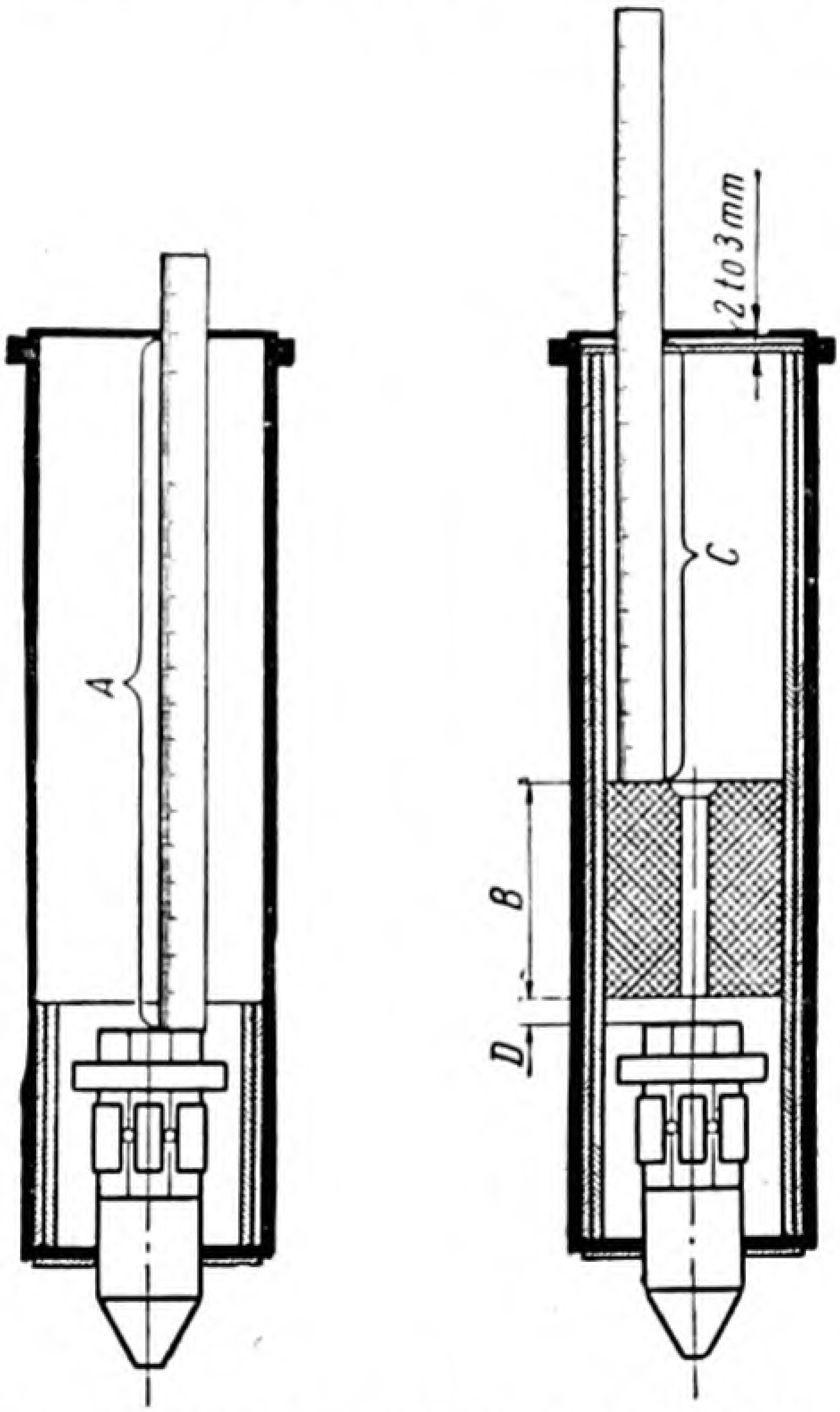


Fig. 94 Setting of the arc-control chamber in the МГГ-10 circuit breaker

A plumb-bob dropped from a point midway between the two pots of a phase (370 : 2=185 mm; see Fig. 86) should come within not more than 3 mm of the midpoint of connection between the rocking lever and the insulating lift rod.

If necessary, the pots and their support insulators together may be slightly shifted relative to the frame owing to the clearance in the frame holes The fastening of the support insulators (Fig. 95) also permits vertical adjustment of the pots.

Mounting of the breaker contacts. The arcing (or contact) rods should first be cleaned and lowered as far as the bottom of the cluster contacts. Then the insulating lift rods, moving operating contacts and crossheads are put in place, and the lower ends of the insulating lift rods are connected to the breaker mechanism.

The arcing rods are then pulled out of their pots and secured to their crossheads temporarily, and the pots are finally aligned and secured so that the arcing rods pulled out of them will enter accurately their holes in the crosshead. The arcing rods are locked in the uppermost position to prevent them from reaching the bottom of the cluster contacts.

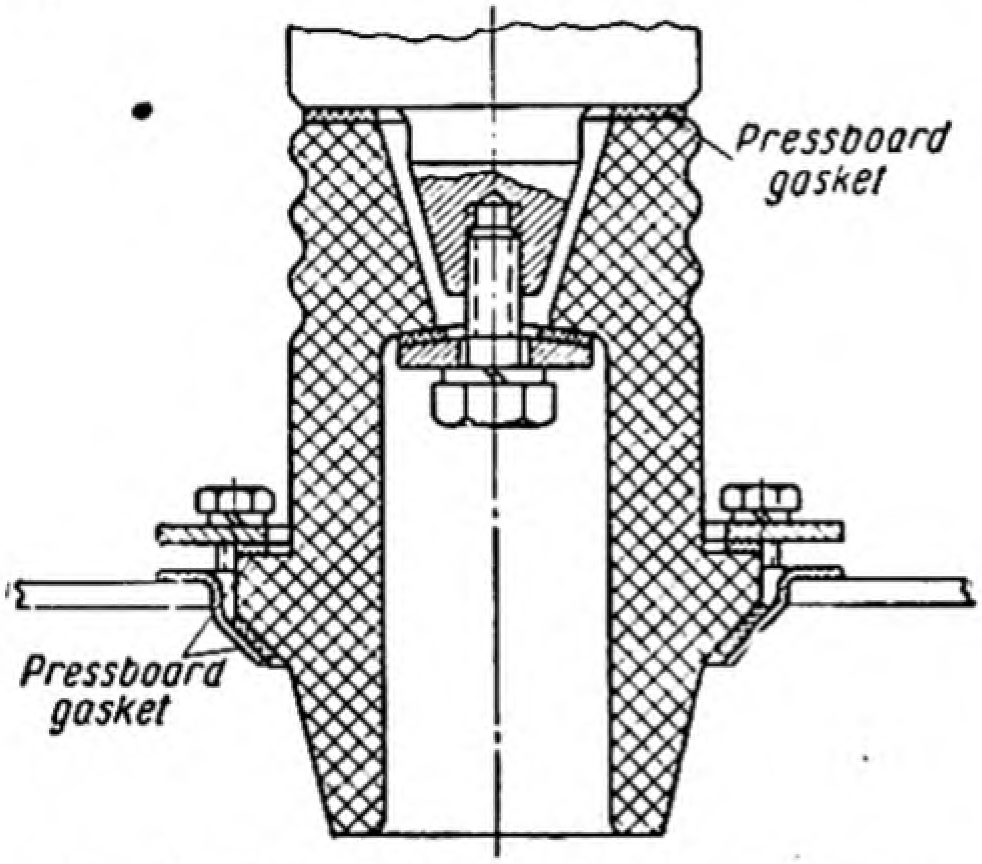


Fig 95 Fastening of the support insulator

Prior to adjustment, the pots should be filled with pure transformer oil, so should the oil dashpots *4* (Fig. 91) which must be filled with Grade "C" machine oil to about half their height.

Adjustment of the circuit breaker and its operating mechanism for joint operation. Adjustment is commenced when the circuit breaker has been mounted. First the length of the tie rod which links the circuit breaker to the operating mechanism should be adjusted so that when the operating mechanism is in the closed position, the circuit breaker is also closed. In the closed position the roller shaft *3* (see Fig. 85) in the operating mechanism should bear upon the hold-in latch *2*. In the closed position, the breaker linkage is locked by stops *5* (see Fig. 91). When adjusting the length of the tie rod, its end should be screwed at least 25 mm into the adapter.

Next the travel of the movable contacts of the breaker is checked. Using a screwjack, the circuit breaker is fully opened, i.e., until

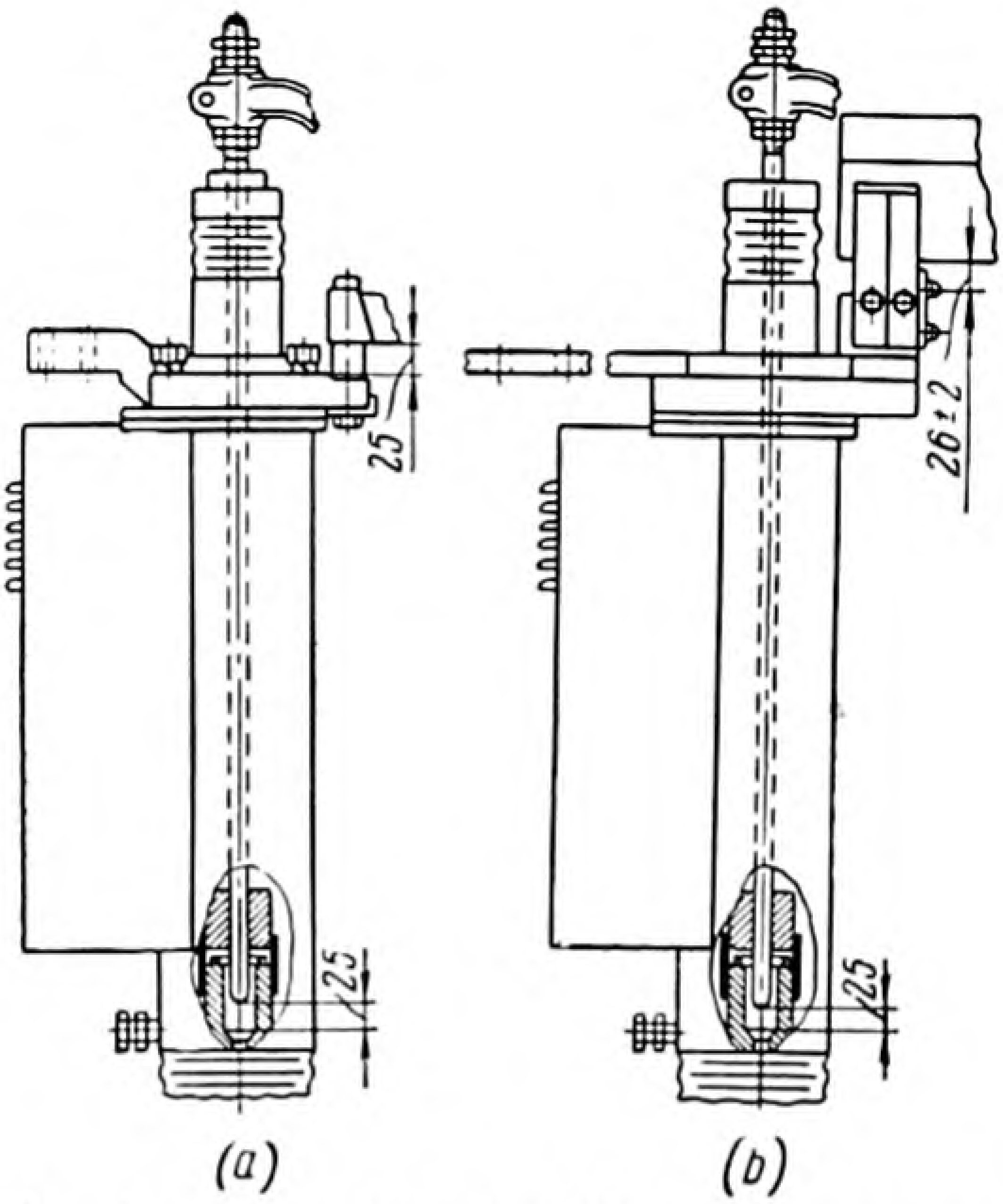


Fig 96. Breaker contacts in the closed position:
a—for 2,000-a breaker; *b*—for 3,000-a breaker

the breaker linkage comes against the stops *5* near the oil dashpots *4*. The contacts should normally move 290 to 300 mm.

After that the main contacts are adjusted. The main contacts should be set as shown in Fig. 96 by adjusting the length of the lift rods.

Then come the arcing rods which are adjusted for their travel in the cluster contacts, which normally is 90 to 95 mm. The instant when the contacts touch each other is determined by means of a simple test lamp circuit in which the lamps light up just as the contacts meet.

16. Mounting of МГГ-229 Oil Circuit Breakers

The МГГ-229 is also a generator-current oil circuit breaker of the minimum-oil class designed for indoor installation in heated and unheated locations. It is used in circuits of large current-carrying capacity (up to 5,000 amperes). This circuit breaker weighs about 2,000 kg dry and takes 54 kg of oil.

A general view of the circuit breaker can be seen in Fig. 97.

This oil circuit breaker comes from the manufacturer's works with its linkage locked in the closed position and in a common packing

crate with its oil baffle chambers *19* and gas vent pipes *16* (Fig. 98) detached for transportation. This crate also holds a spanner for unscrewing the cluster contacts and the telescopic screwjack, by the aid of which the breaker can be closed and opened manually.

The breaker linkage is locked by a shackle which secures the lever of the main shaft *4* to the frame *5* of the circuit breaker.

After unpacking, the circuit breaker is thoroughly inspected externally and checked for broken porcelain insulators and missing parts.

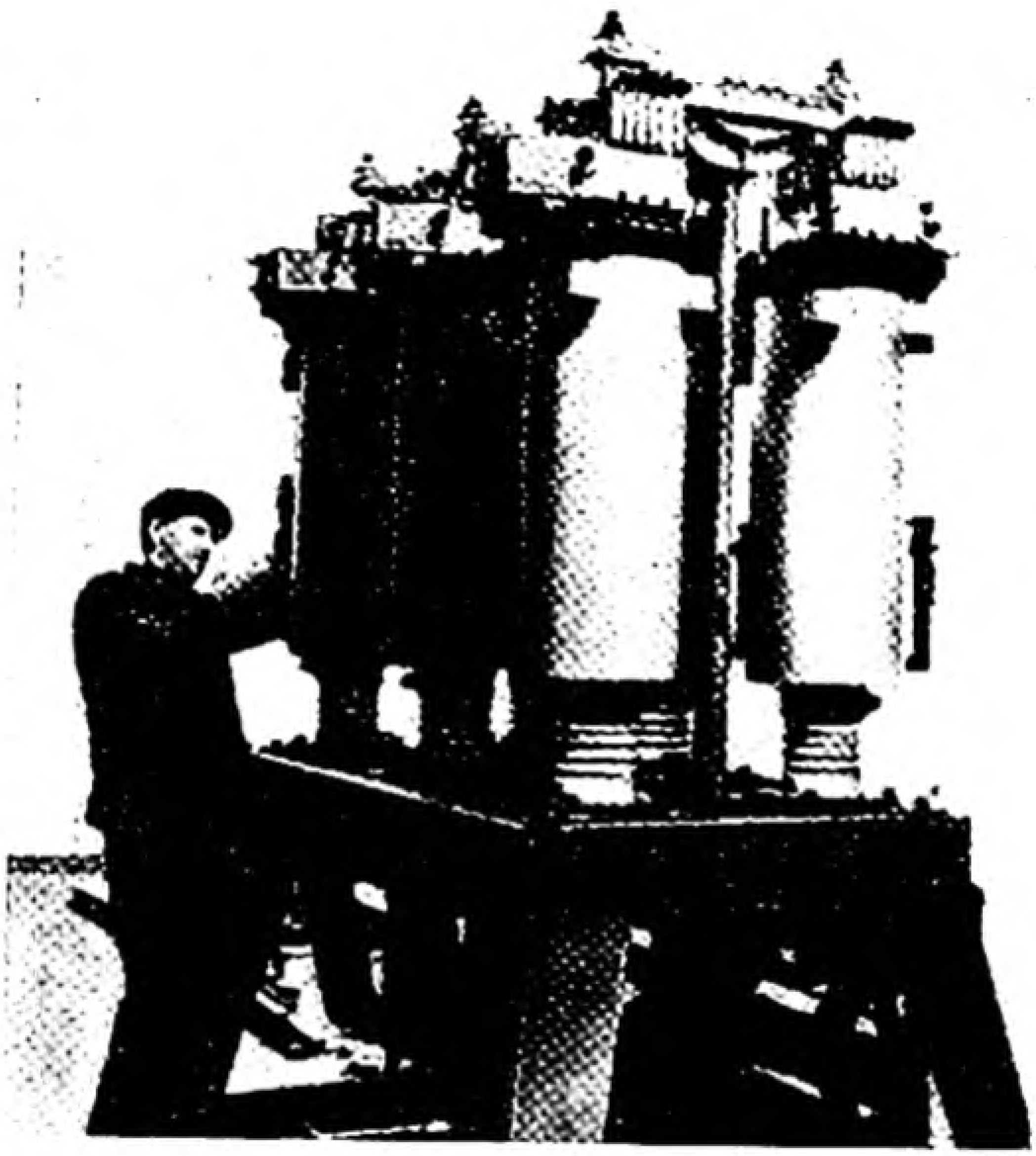


Fig. 97. General view of the МГГ-229 oil circuit breaker (with the oil baffles and the vent pipes removed)

Mounting of the circuit breaker and operating mechanism. The circuit breaker is moved into its permanent position by means of rollers and a hand-operated or an electric winch.

By that time the builders should have prepared the holes in the floor or foundation for the anchor bolts with which the circuit breaker is to be secured in place.

The bolt holes for the МГГ-229 breaker are laid out as shown in Fig. 99 and the bolts to use are ten M20 anchor bolts.

The fastening procedure for this circuit breaker is the same as for the МГГ-10 (refer to Sec. 15).

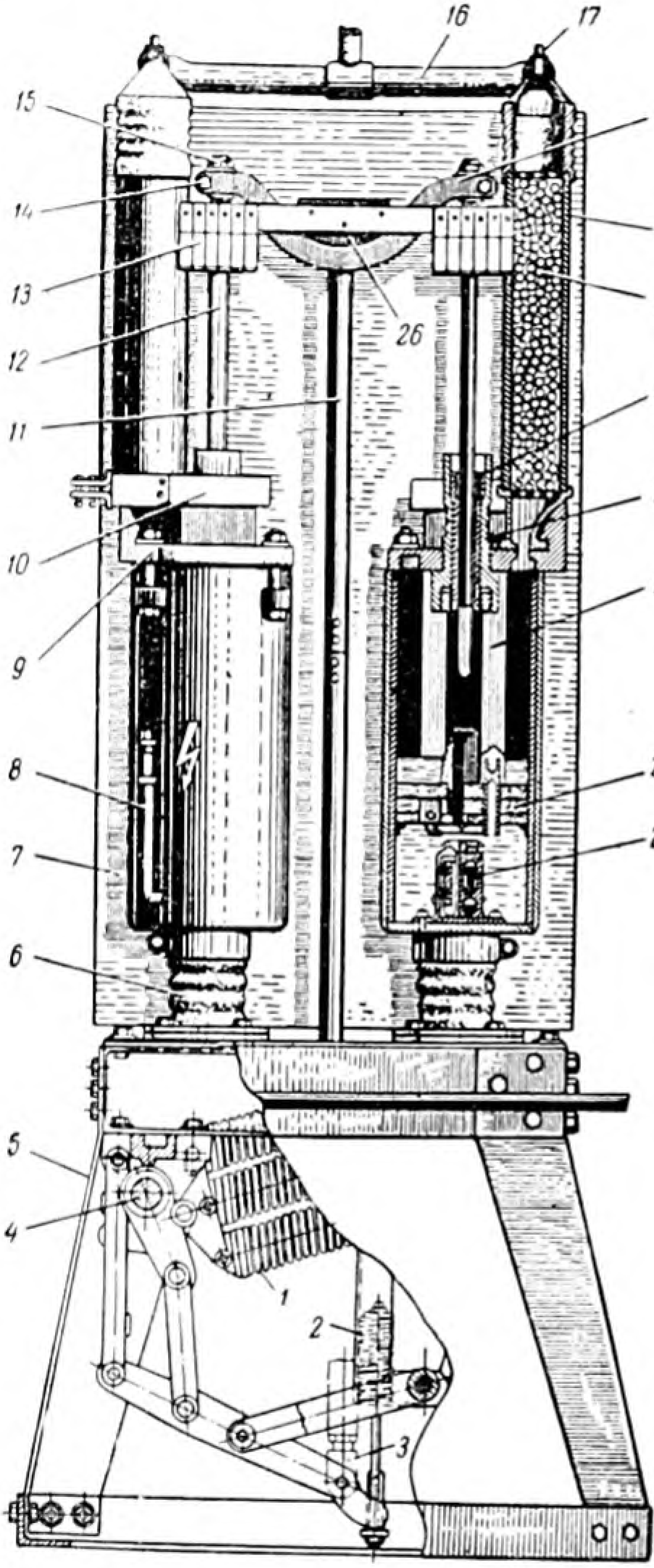


Fig. 98. Sectional view of the МГГ-299 oil circuit breaker:

1— opening springs; *2*— spring buffer, *3*—lift rod end fitting; *4*—main shaft of breaker; *5*—frame; *6*—support insulator; *7*—insulating barrier; *8*—oil gauge; *9*—pot cover; *10*—fixed contact blades; *11*—insulating lift rod; *12*—arcing rod; *13*—moving load current contact; *14*—clamping bolt; *15*—arcing rod lock nuts; *16*—gas vent pipe; *17*—thrust bolt; *18*—crosshead; *19*—oil baffle tube; *20*—porcelain balls or pebbles of oil baffle; *21*—arcing rod packing; *22*—bushing; *23*—insulating sleeves; *24*—arc-control chamber; *25*—cluster contact; *26*—current conducting cross bar

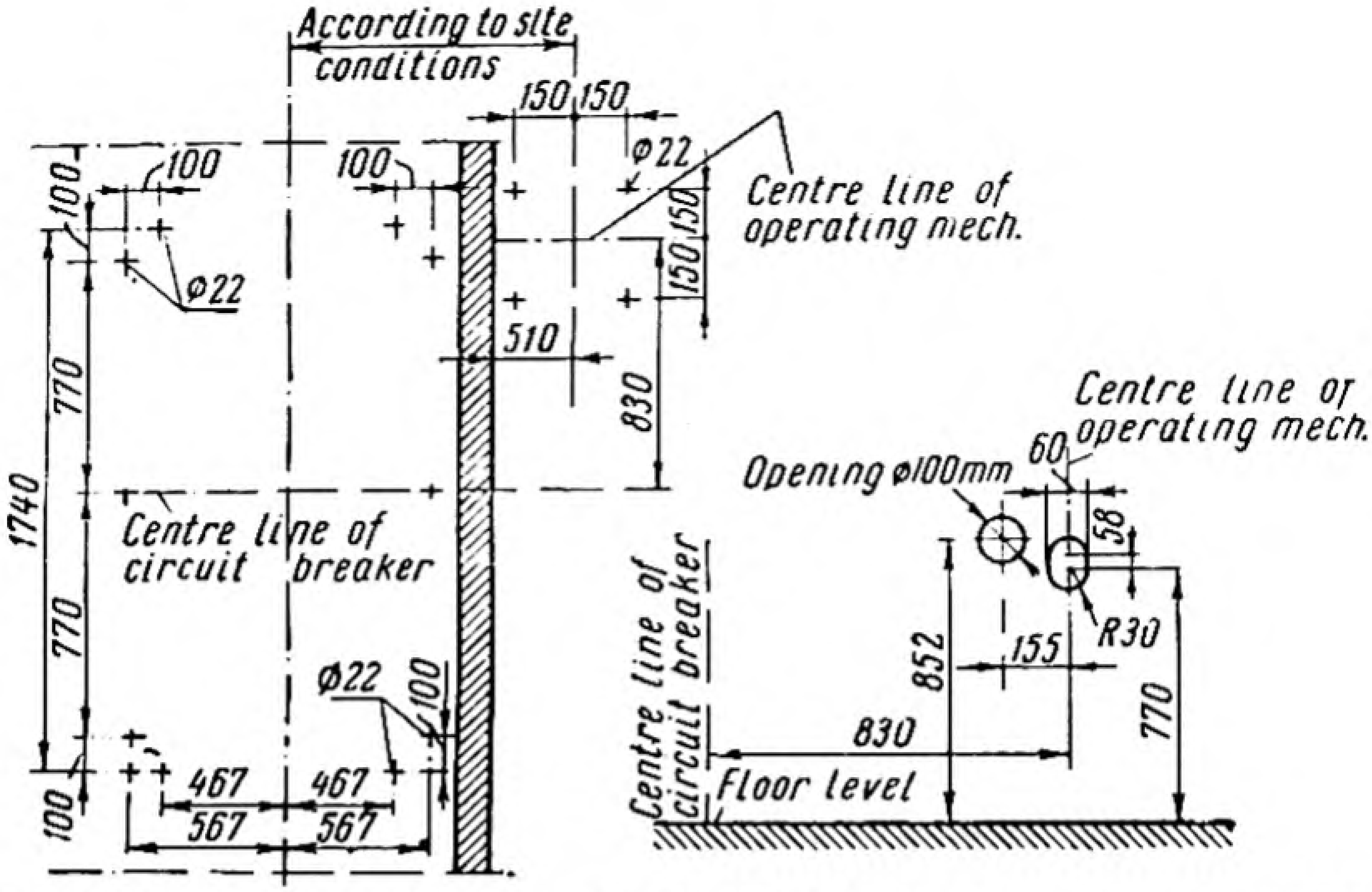


Fig. 99. Layout drawing for mounting of a МГГ-299 circuit breaker and its ПС-30 solenoid operating mechanism

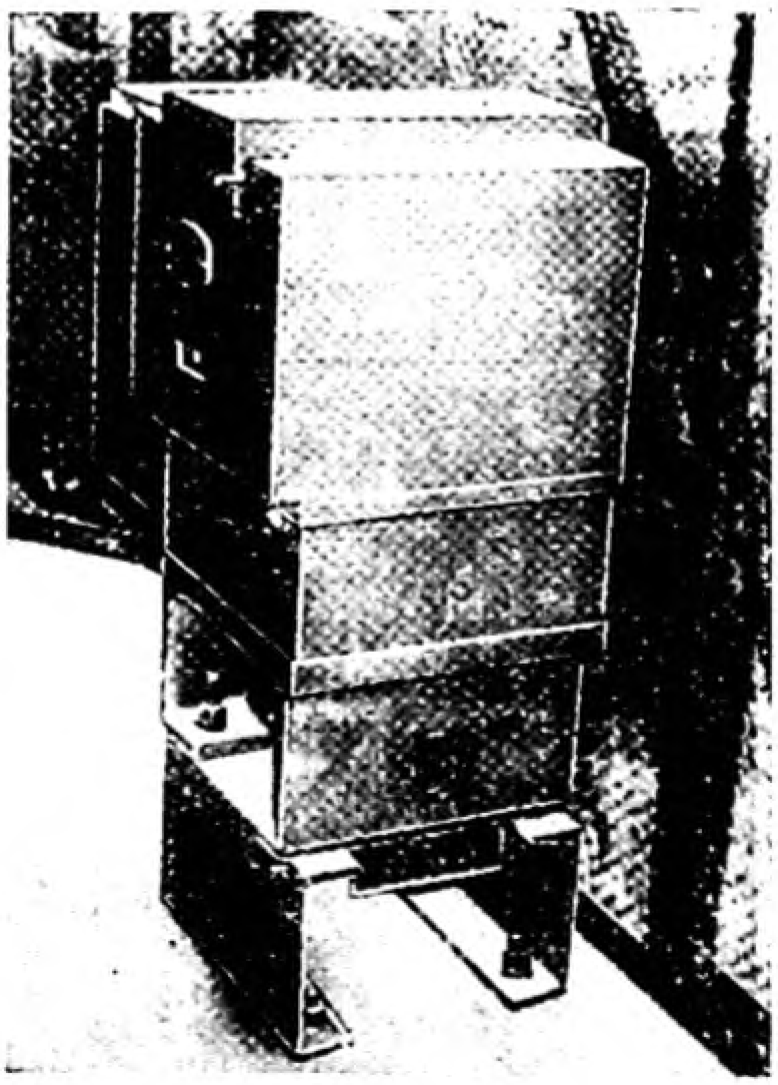


Fig 100 General view of the ПС-30 operating mechanism

A ПС-30 solenoid mechanism weighing 475 kg is used to operate the МГГ-229 oil circuit breaker.

A general view of this operating mechanism is shown in Fig. 100; its installation dimensions are given in Fig. 99.

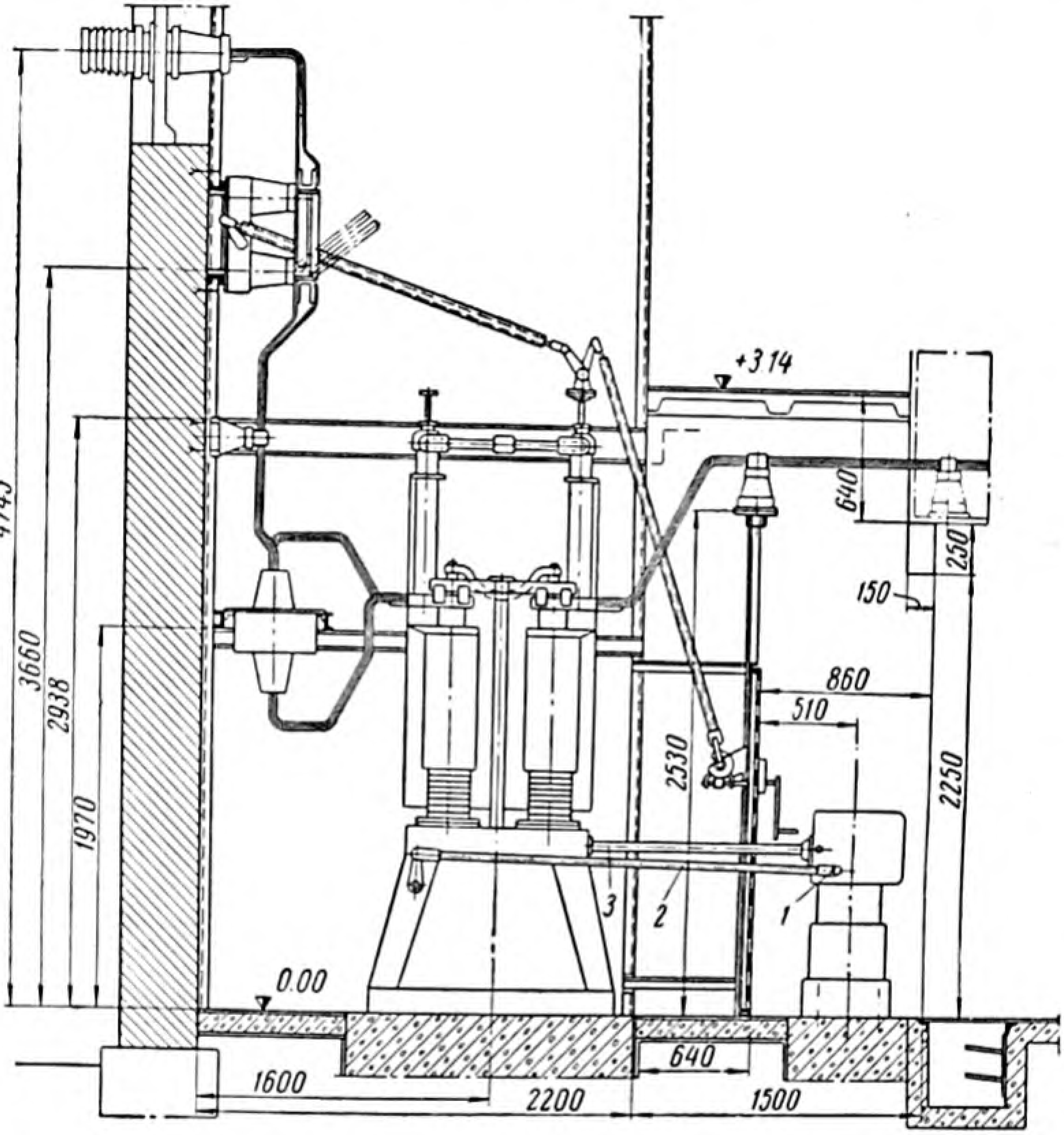


Fig. 101 Installation drawing for the МГГ-299 circuit breaker and its ПС-30 operating mechanism:

1—tie rod end fitting; *2*—pipe tie rod; *3*—strut

The ПС-30 solenoid operating mechanism is usually mounted on short lengths of Nos 16a or 16b steel channels with M20 bolts which are also used to secure the channels to the floor.

The circuit breaker and the operating mechanism (Fig. 101) are linked up by a tie rod *2* of $1\frac{1}{4}$-inch pipe with end fittings *1*. Both ends of the tie-rod pipe are threaded so that they can be screwed at

least 35 mm into the end fittings. One end of the tie rod is attached to the arm on the breaker shaft, the other end, to the arm of the operating mechanism.

In addition, a brace *3* which is a 2-inch pipe, is placed between the circuit breaker and operating mechanism. One end of the brace is screwed into a flange on the operating mechanism frame, and the other end is made to bear against the breaker frame. The end at the operating mechanism must be screwed at least 35 or 40 mm into the flange. The brace makes for greater rigidity of the system.

Internal inspection of the apparatus. After the circuit breaker and its operating mechanism have been mounted, a telescopic jack (Fig. 102) is placed under the lower end of the plunger between the feet of the operating mechanism (much as in the case of the МГГ-10 breaker); the breaker is pushed past the closed position by means of the jack to release the shackle which has kept the breaker in the closed position, the shackle is then removed and the breaker is slowly opened.

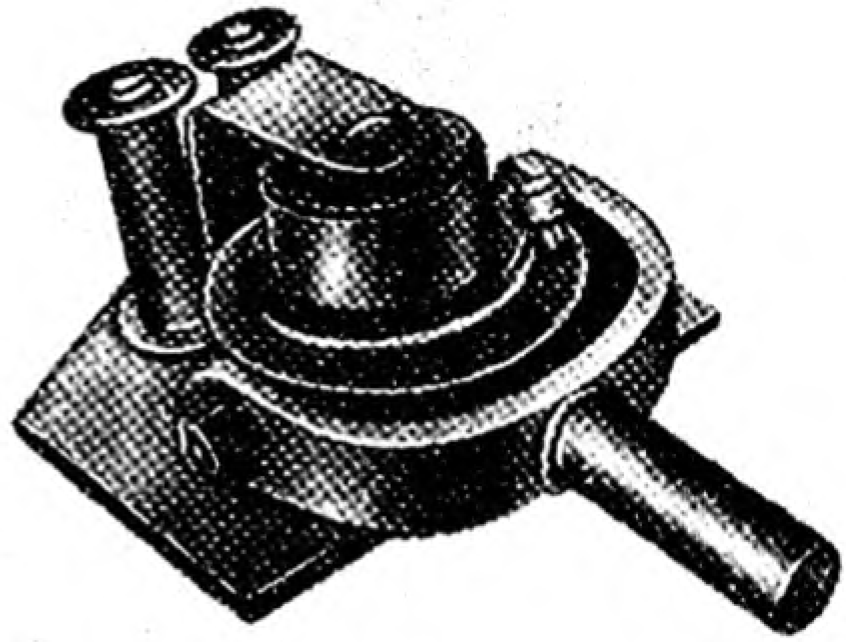


Fig. 102. Jack used for manual closing in adjustment

With the breaker open, the nuts *15* (see Fig. 98) which secure contact (arcing) rods *12* are unscrewed and the clamping bolts *14* are slackened. The arcing rods are then lowered until they come abutt with the bottom of the pot.

To obtain access to the internal parts of the breaker pot, the insulating lift rod *11* is disconnected and removed together with the crosshead. Next the arcing rods are taken out, the covers *9* removed, and the control chambers *24* together with the insulating members *23* lifted out.

Using the spanner furnished with the breaker, the four nuts fastening the cluster contact *25* in the bottom of the pot are slackened, the contact is turned clockwise by hand until the slots in its base are in line with the nuts, and the contact is removed from the pot.

All the parts are collected in a suitable place where they can be inspected and wiped clean. The metal parts should be wiped with a rag soaked with petrol, and the insulating parts, with a dry rag.

In the case of an interruption in the work, the opened pots must be covered with clean rags or paper to shut out any dirt or impurities.

After internal inspection, the circuit breaker is re-assembled. First the cluster contact is mounted so that it is placed precisely in the centre of the pot bottom. Next the side-blast (arc-control) chambers are installed, to be followed by the pot cover. Before the covers are bolted in place, the arcing rods should be checked to see that

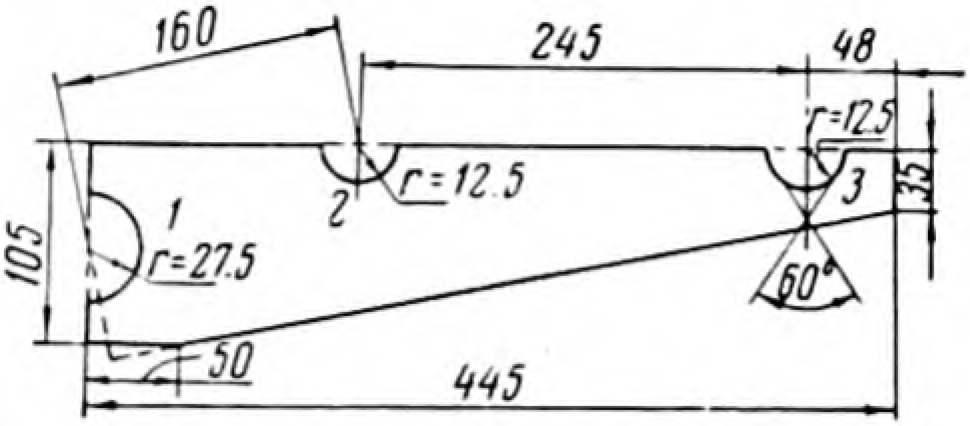


Fig 103. Template for checking МГГ-299 circuit breaker mechanism

they are free to pass through the bushing and the side-blast barrier and that the flexible lead located under the pot cover is fully compressed.

With the arcing rods lowered through the bushings until they are abutt with the bottoms of the pots, the insulating lift rod and crosshead are mounted, and the lower end fitting *3* of the lift rod (see Fig. 98) is attached to the circuit breaker mechanism.

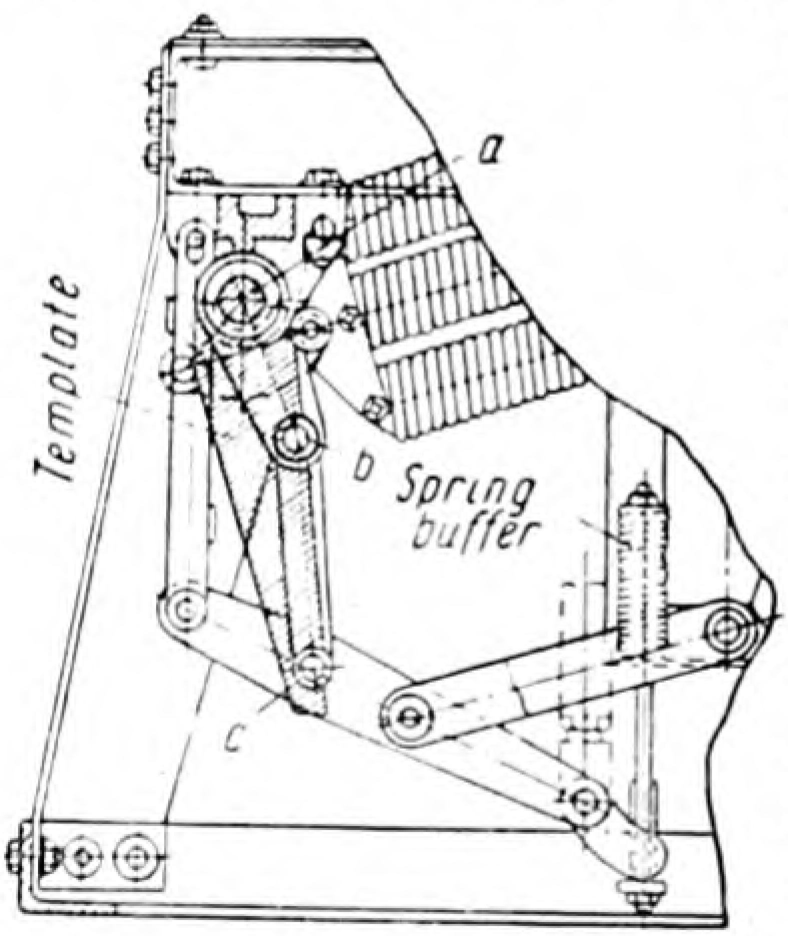


Fig. 104. Checking of МГГ-299 circuit breaker mechanism

The arcing rods are then lifted from the pots and secured in the crosshead, the latter being in the uppermost position so that the rod cannot strike the pot bottom.

Adjustment of the circuit breaker and operating mechanism for joint operation. This is done by adjusting the length of the tie rod *2* (see Fig. 101) by means of its end fitting *1*. For adjustment purposes the circuit breaker is opened and closed with the aid of a screw-jack.

Concurrently with tie-rod length adjustment the length of the insulating lift rod *11* is also adjusted. This is done by screwing the end fitting *3* in or out (see Fig. 98) so that in the closed position the shafts of the breaker mechanism are brought into a relative arrangement corresponding to a template. In other words, with the tem-

plate placed against the shafts, points *1*, *2* and *3* (Fig. 103) should coincide with points *a*, *b* and *c* of the breaker mechanism (Fig. 104). The tolerance ("underclosure") for the middle shaft is 3 mm.

Next the travel of the crosshead is adjusted so that it is anywhere between 440 and 410 mm (420^{+20}_{-10}). The oil dashpots of the breaker are filled with oil two-thirds full and adjusted so as to eliminate any rebound when the breaker is opened.

Then comes the adjustment of the breaker contacts—an extremely important and responsible operation. For this adjustment, the circuit breaker is opened, and the protective grease is removed from its contacts. Then the circuit breaker is reclosed by means of its operating mechanism (at normal voltage) and the distances from the tops of the blade contacts *10* to the current-conducting crossbars *26* (see Fig. 98) are checked. They should be 22±1.5 mm; otherwise the end fitting *3* on the lift rod should be screwed in or out, as the case may be.

When the distances measured on the pots of any one pole differ by more than 3 mm, the respective tank should be lifted or lowered by means of washers placed under the base of the support insulators.

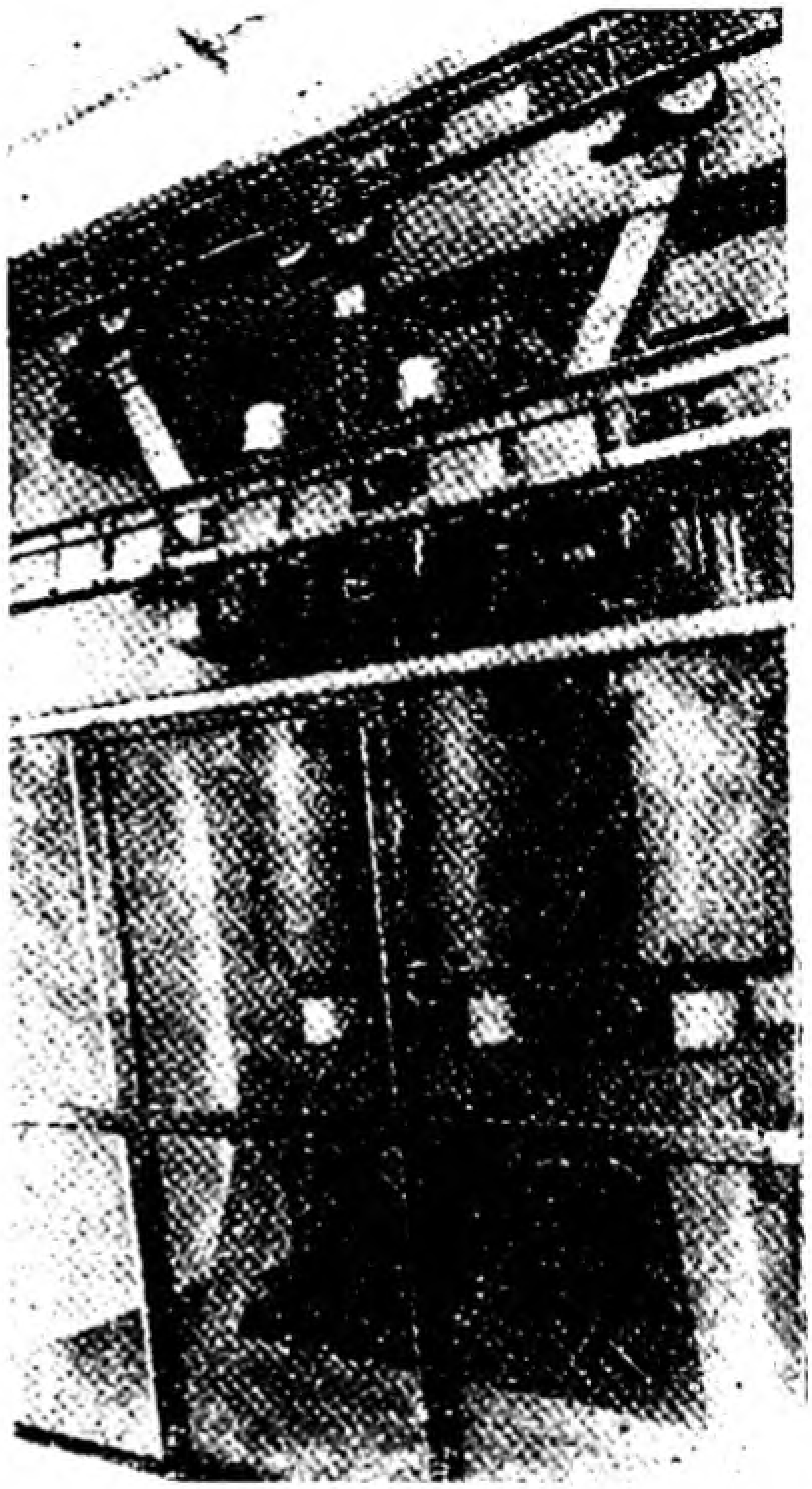


Fig. 105. МГГ-299 circuit breaker in place in a station switchgear room

Each pole is then checked to see that on a closing stroke all the finger contacts touch the blade contacts simultaneously. They may be considered to do so if, when the breaker is slowly closed by means of a screwjack, the crosshead moves through not more than 5 mm between the moments when the first and last fingers touch their blade contacts.

The pressure of the finger contacts on the blade contacts is next measured with a dynamometer and should be 14±1 kg. The pressure of one finger contact in each pair should be measured. If the pressure is insufficient, the contact springs are tightened.

After the adjustment, the contact surfaces of the fingers and blades as well as all external current-carrying parts are wiped with a clean cloth moistened with petrol and are given a thin coat of petroleum jelly. The arcing rods are then secured in the crosshead so that, when the circuit breaker is closed by its solenoid operating mechanism at the normal control voltage, the arcing rods stop within 20 or 25 mm of the pot bottom.

The oil baffle tubes *19* and gas vent pipes *16* may now be mounted (see Fig. 98). The former are seated on gaskets of rubberised composition or asbestos, and the gas vent pipes are then set up. Next the thrust bolts *17* are unscrewed from the head of the oil-baffle tubes until they come against the beams in the upper part of the cell (see Fig. 101) and then their lock nuts are tightened. The thrust bolts should be tightened with care so as not to misalign the breaker pot.

The interphase barriers are attached to the upper part of the breaker frame and to the channels against which the thrust bolts of the oil-baffle tubes are forced.

When breakers are installed not near one another, two-inch gas vent piping is run directly outdoors. When circuit breakers are mounted in groups, the gas vents are connected by means of two-inch pipes to a common four-inch gas manifold.

In the former case, the pipe ends must be fitted with either a flap valve or by easily-replaceable parchment membranes. The outlets of the gas vent pipes must be turned downward.

Problem. Write up an operation sequence for mounting of an МГГ-229 oil circuit breaker in a switchgear cell (Fig. 101).

17. Mounting of Instrument Current Transformers

Indoor substations widely use ТПФ porcelain bushing current transformers, and ТПФМ current transformers ("M" stands for "modernised").

Fig. 106 gives the installation dimensions of ТПФ current transformers which weigh from 35 to 45 kg.

Also, though on a smaller scale, use is made of ТПОФ and ТПШФ current transformers, the letter "O" standing for "single-turn", and the letter "Ш" for "window-type".

The dimensions of some of these current transformers are given in Figs 107 and 108, and in Tables 10 and 11.

Checking of current transformers prior to mounting. Current transformers received for mounting must first be checked for the condition of their porcelain insulators and current-carrying rods or bars. They must meet the same requirements as bushings do (see Sec. 9). The

secondary terminal blocks are also checked for breakage, lead markings and the nameplate, while the casing and flanges are examined for dents.

On the site, the checking of current transformers is usually limited to visual inspection, as they come already checked for the

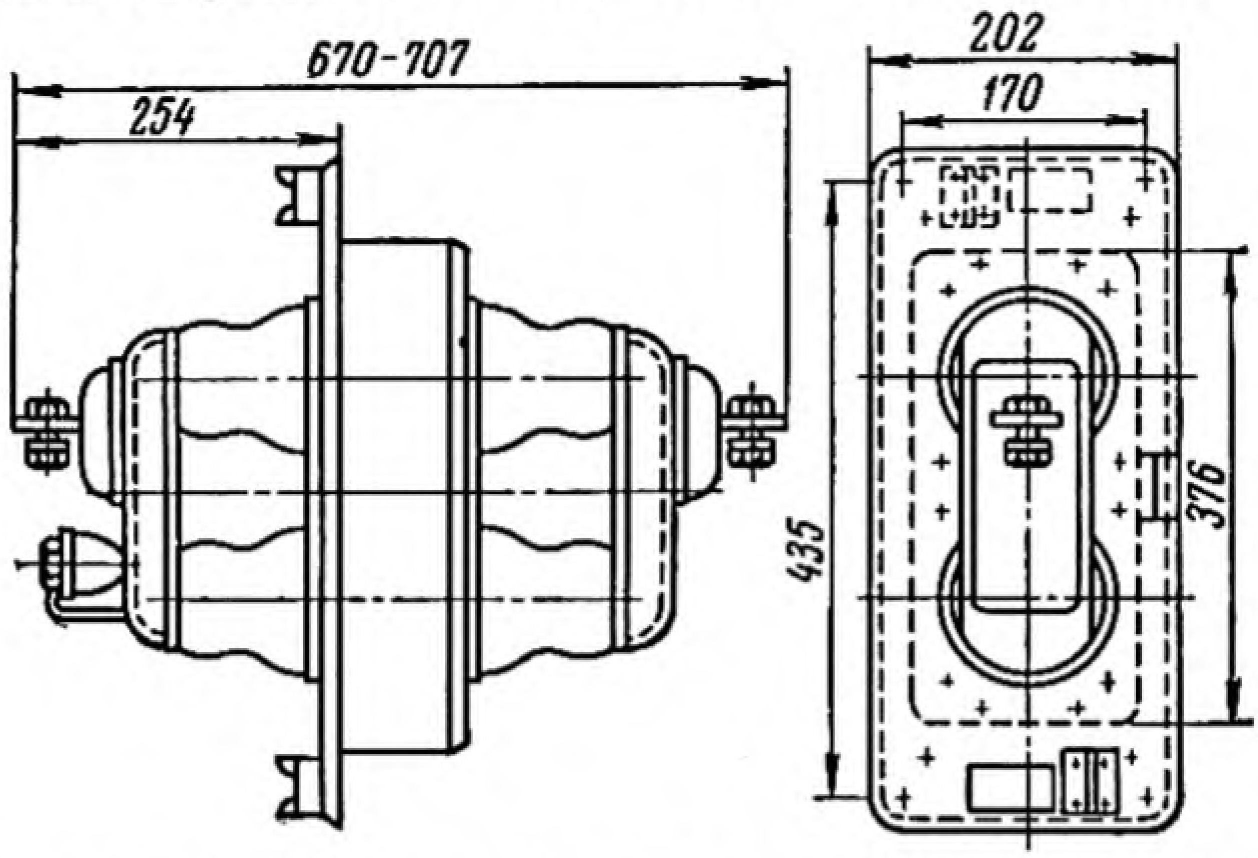


Fig 106. Installation dimensions of a ТПФ current transformer

continuity of the secondary, the insulation resistance of the windings, polarity of the terminals and the transformation ratio either in a specialised workshop or laboratory, or by special personnel.

Table 10

Dimensions and Weight of Several ТПОФ Current Transformers

Type designation	Dimension *A* (in Fig. 107), mm	Weight, kg
ТПОФ-10-0.5-600	630	50
ТПОФУ-10-3-600	660	42
ТПОФД-10-Д-600	580	36

Note: In the type designations the letter У stands for "increased strength", the letter Д, for "differential protection" and the numerals "0.5" and "3" denote the accuracy class.

In some cases, however, it may be necessary for the electricians to do this checking themselves. Therefore, we shall outline the fundamental features and techniques of the respective tests in brief.

The continuity of the secondary can be checked by means of the circuit given in Fig 109*a*. If there is no break in the winding, the

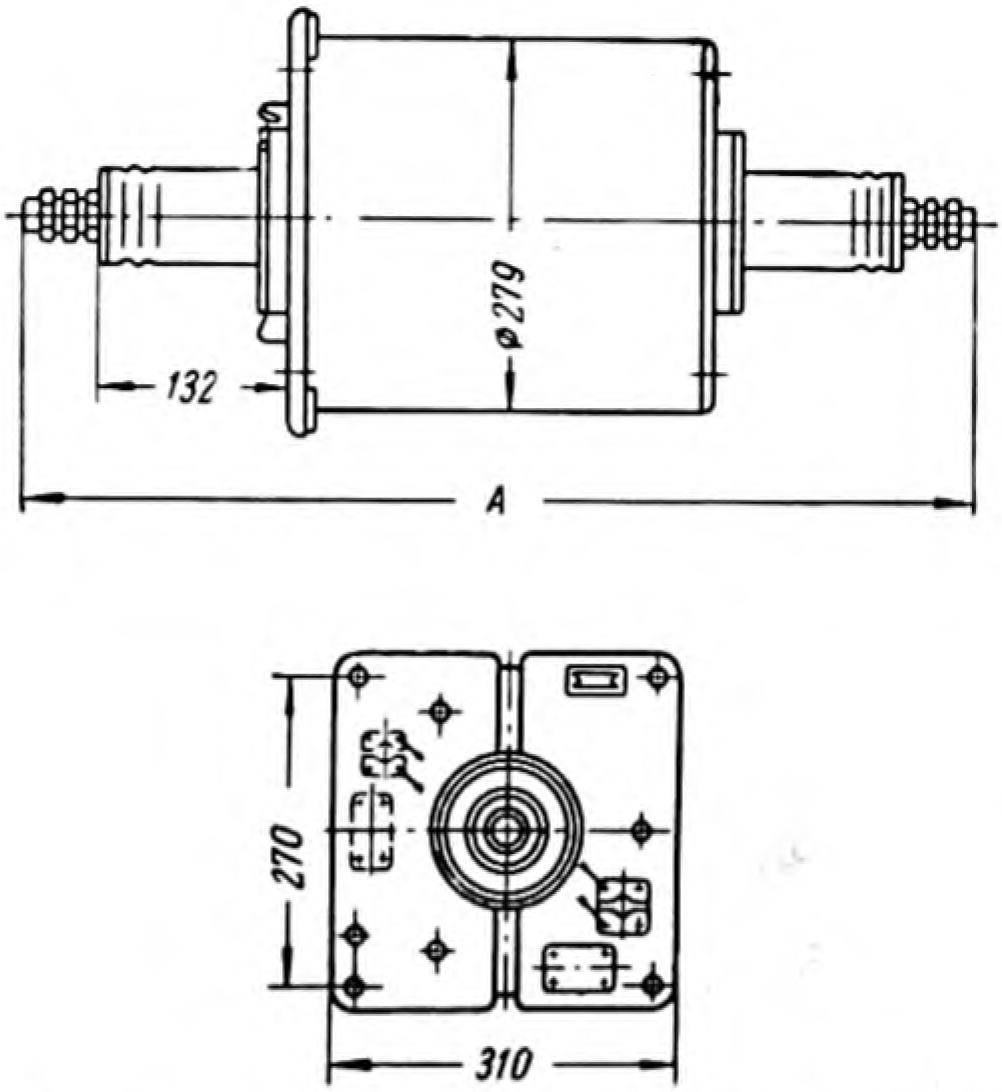


Fig. 107. Installation dimensions of a ТПОФ current transformer

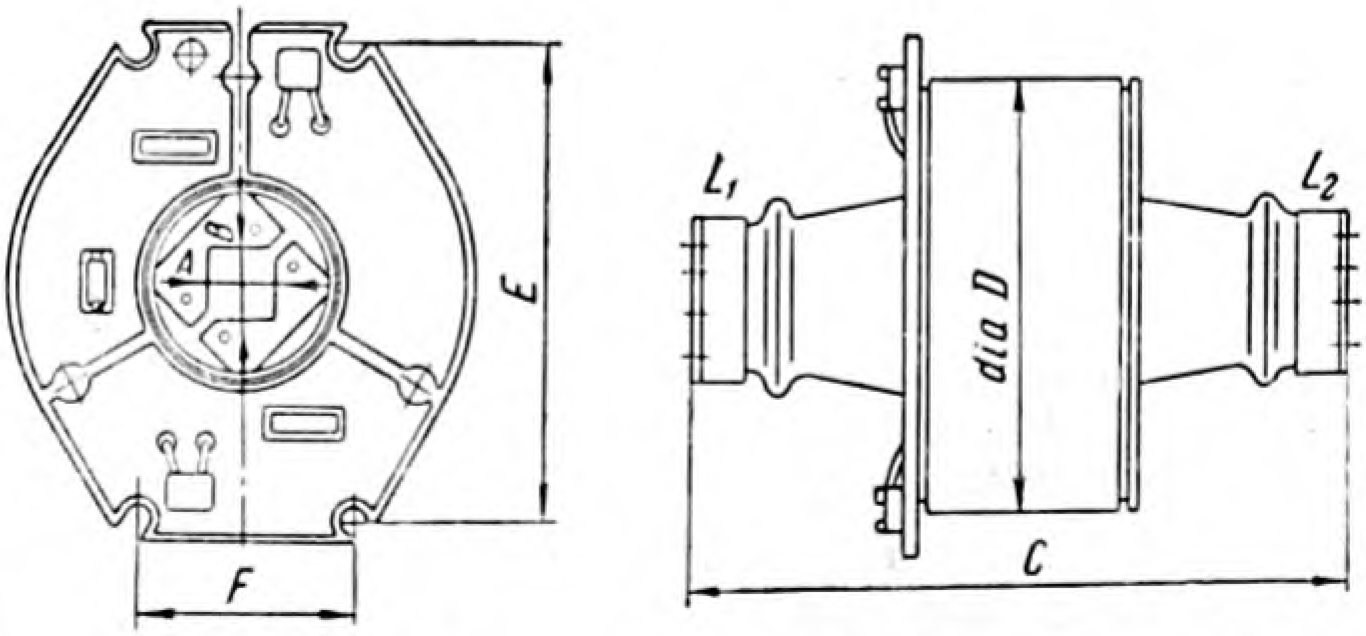


Fig. 108. Installation dimensions of a ТПШФ current transformer

Table 11

Dimensions and Weight of Several ТПШФ Current Transformers

Type designation	Dimensions (in Fig. 108), mm						Weight kg
	A	B	C	D	E	F	
ТПШФ-10-0.5-4000-5000	71	101	606	428	462	240	90
ТПШФ-10-0.5/0.5-2000-3000	61	61	606	391	426	200	87

pointer of the megohmmeter tester will deflect across the entire scale when the handle is cranked. When a break exists in the winding, the pointer will remain at zero.

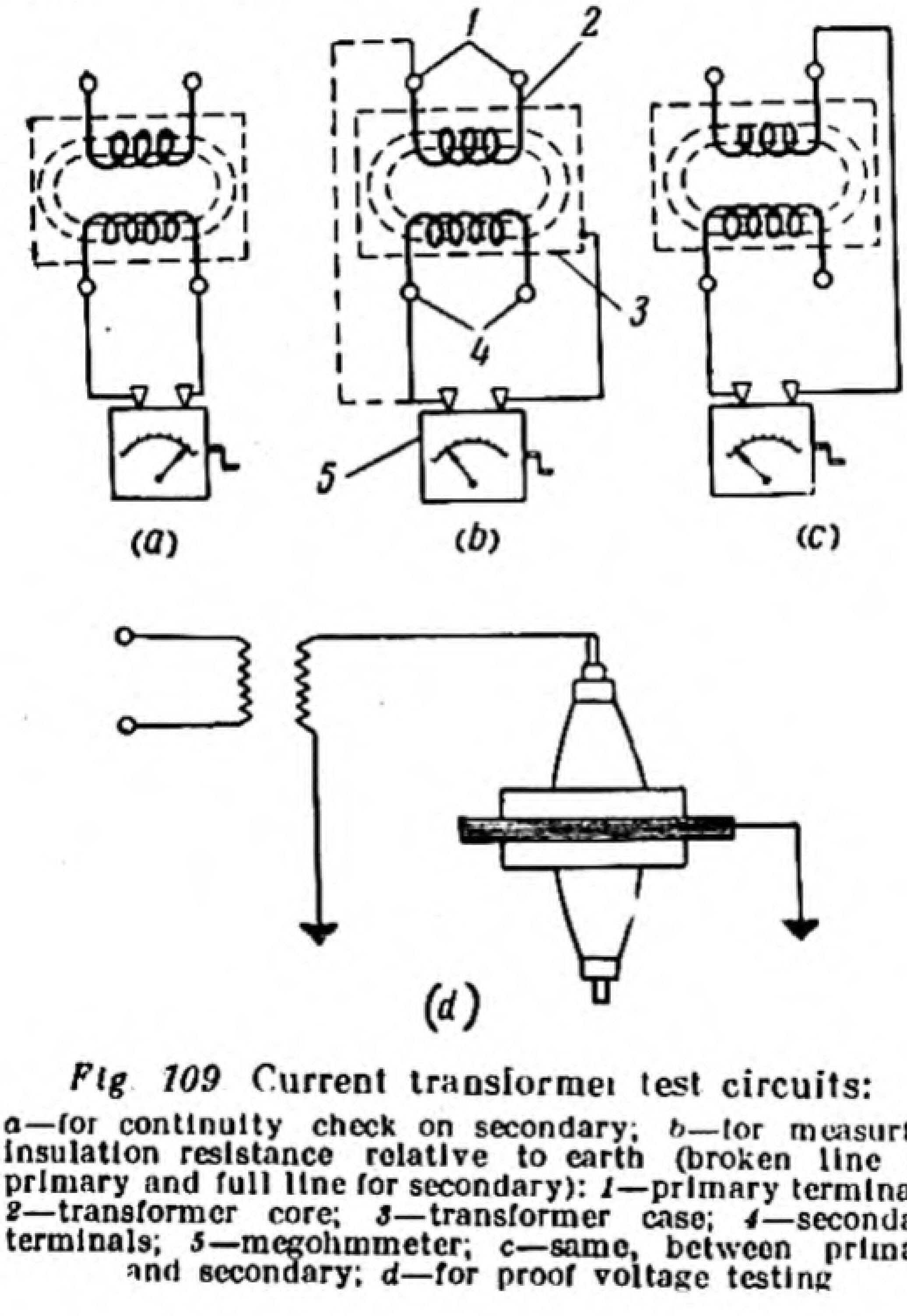


Fig. 109 Current transformer test circuits:

a—for continuity check on secondary; b—for measuring insulation resistance relative to earth (broken line for primary and full line for secondary): 1—primary terminals; 2—transformer core; 3—transformer case; 4—secondary terminals; 5—megohmmeter; c—same, between primary and secondary; d—for proof voltage testing

The insulation resistance is measured by use of the schemes given in Fig. 109*b* and *c*. The insulation resistance of the secondaries, when measured by a 1,000-volt megohmmeter, must be no less than 10 megohms. The insulation resistance of the primaries is not subject

to standards, but when it is measured by a 1,000-volt megohmmeter it should be of the order of 20 to 25 megohms.

Current transformers are also subjected to a proof voltage test during which their secondary windings must withstand a test pressure of 2,000 volts at power frequency for one minute.

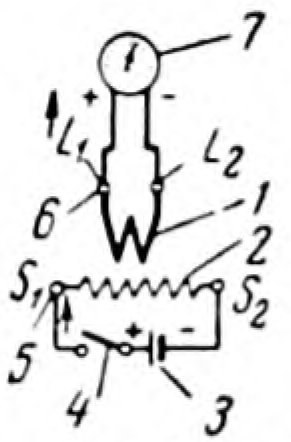


Fig. 110. Winding polarity test circuit:

1—primary; *2*—secondary; *3* — dry cell; *4*—switch; *5* and *6*— winding terminals; *7*—galvanometer

Primary insulation should withstand the test voltage given in Table 32 for one minute. The test circuit is illustrated in Fig. 109*d*.

If the insulation fails to meet standard requirements, it should be dried out either by passing current through the primary while the secondary is short circuited, or by passing current through the secondary while the primary is short circuited.

During drying-out the temperature of the insulation should not rise above 65°C, and that of the metal parts, over 85°C. The currents in the windings should be 20 to 25 per cent above their ratings. The casings should be removed for free escape of the moisture evaporated from the windings.

The polarity of a current-transformer winding is determined by means of the test circuit shown in Fig. 110. Direct current is taken from a 2- to 4-volt source. If the polarity is as shown in Fig. 110,

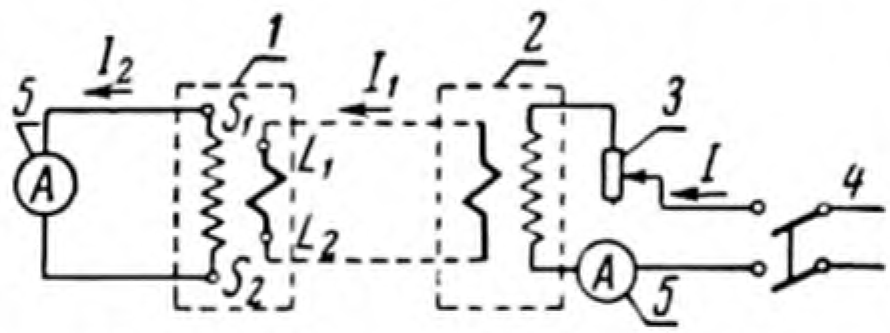


Fig. 111. Current transformer ratio test circuit:

1—transformer under test; *2*—laboratory transformer; *3*—rheostat; *4*—source of 6-12 volt ac; *5*—10-a range ammeter

the instrument pointer should deflect to the right; deflection of the pointer to the left indicates that the polarity of the secondary is the reverse of that shown in the circuit diagram and that its terminal markings must be changed.

The ratio of a current transformer is checked by means of a loading transformer rated for 1,000 to 2,000 amperes and the circuit shown in Fig. 111.

The true ratio of a transformer is determined by the equation:

$$r = \frac{I_1}{I_2}$$

where I_1 is the primary current and I_2 is the secondary current as measured during the test.

Mounting of current transformers. The porcelain-bushing current transformers used in indoor substations of the 6- and 10-kv class

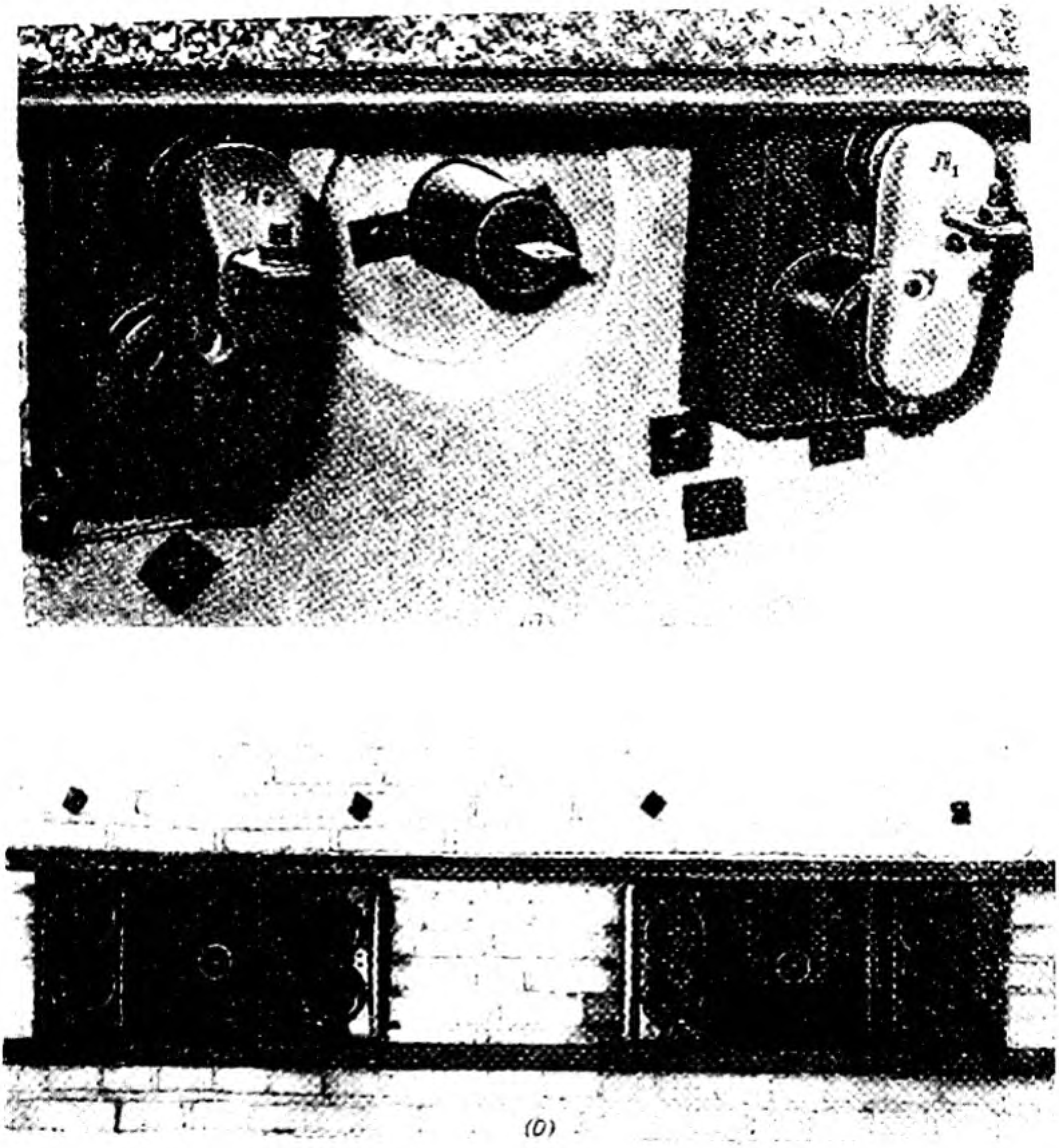


Fig. 112. Current transformer and bushing mounting:
a—in wall openings; b—on embedded channels

serve the dual purpose of a current transformer and a bushing and are hence combined in sets with ordinary wall-type bushings for passage of buses through walls and floors. In view of this, the mounting procedure for them follows that of a bushing (refer to Sec. 9).

Various arrangements of current transformers and bushings can be seen in Fig. 112 and Fig. 113.

When current transformers are mounted in walls or ceilings, a clearance of 3 to 4 mm should be left between the transformer cas-

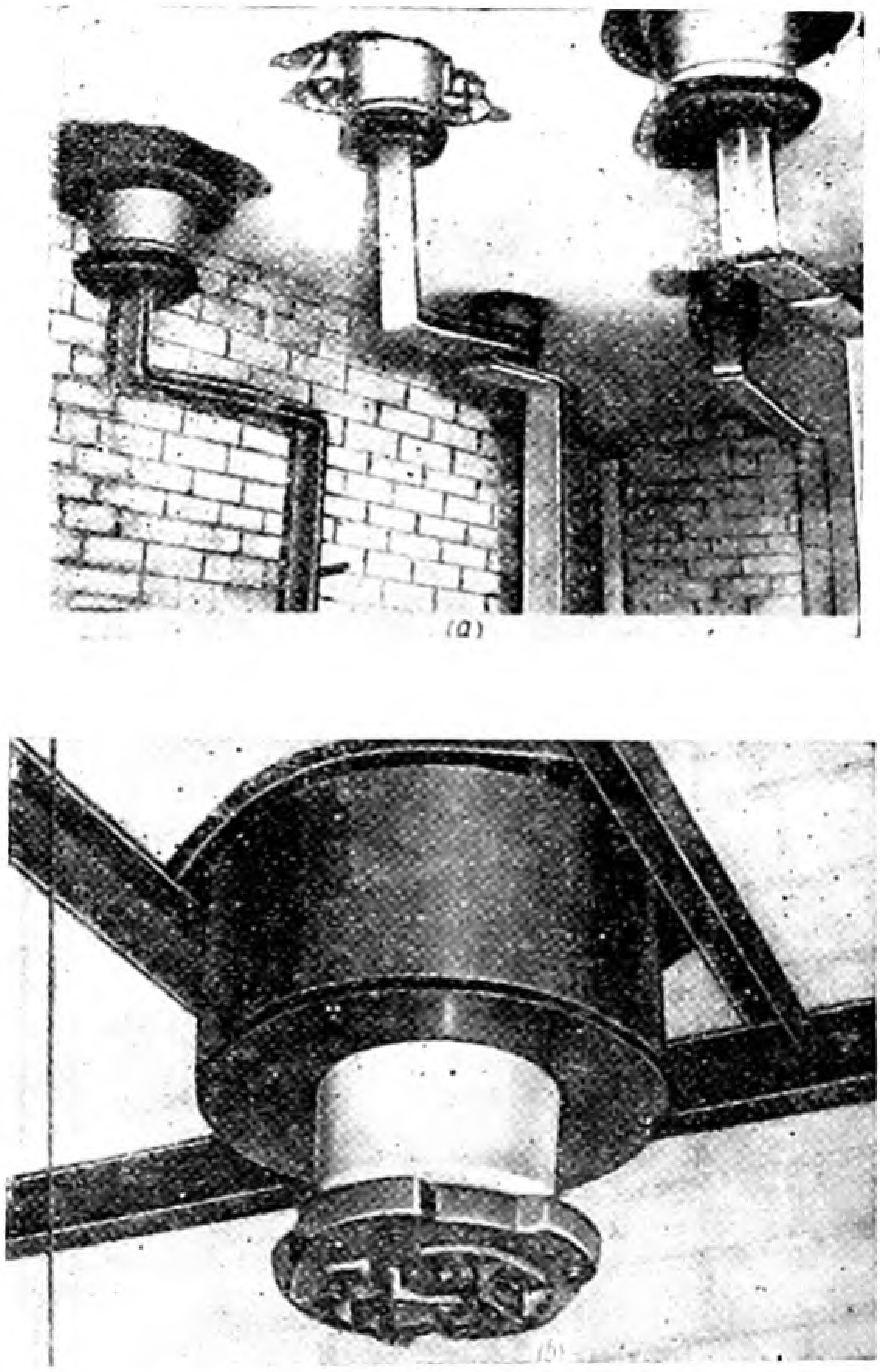


Fig. 113 Mounting of ТПШФ window-type current transformers:
a—in ceiling openings; *b*—on channels

ing and the support surface for a tar-paper gasket to protect the transformer casing from corrosion.

To protect the porcelain parts of current transformers during the installation work, a wooden board should be placed on top of them as shown in Fig. 112*a*.

When several current transformers are used they should have identical ratings which are given on their nameplates, and should be used according to the layout diagrams specifying what type of transformer should be installed in a given compartment.

The terminals of current transformers should be so arranged that the incoming power buses are taken to the terminals marked L_1 and the outgoing buses are connected to the terminals marked L_2. Otherwise, the polarity markings of the secondary windings, S_1 and S_2, will have to be reversed.

Problem. Write up an operation sequence for mounting two ТПФ-10/600 current transformers and a ПА-10/600 bushing on a built-in metal support, as shown in Fig. 113*b*. Assume that the metal support for the current transformer has been provided by builders.

18. Mounting of Voltage Transformers

Types and weights of instrument voltage transformers used in indoor switchgear are summarised in Table 12; their installation dimensions are shown in Figs 114, 115, 116 and 117.

Table 12

Types and Weights of Voltage Transformers

Type designation	Total weight, kg	Weight of oil, kg
НОМ-6	23	4.7
НОМ-10	36	7.5
НТМК-6	47.5	15
НТМК-10	100	27
НТМИ-6	105	32
НТМИ-10	190	70

Note: In the type designations Н denotes "voltage transformer"; О stands for "single-phase"; М, for oil-immersed; Т, for three-phase; К, for "compensating winding"; И, for "test winding", and the numerals, for the kv ratings.

Voltage transformer inspection prior to mounting. Voltage transformers are inspected visually for broken porcelain bushings and cemented joints, for mechanical injury to the tank, and for oil leakage between the cover and tank and from under the bushing flanges. In addition, they are checked for oil level, the condition of the oil gauge and the presence of the nameplate.

The electrical checks of voltage transformers are similar to those of current transformers and involve measurements of insulation re-

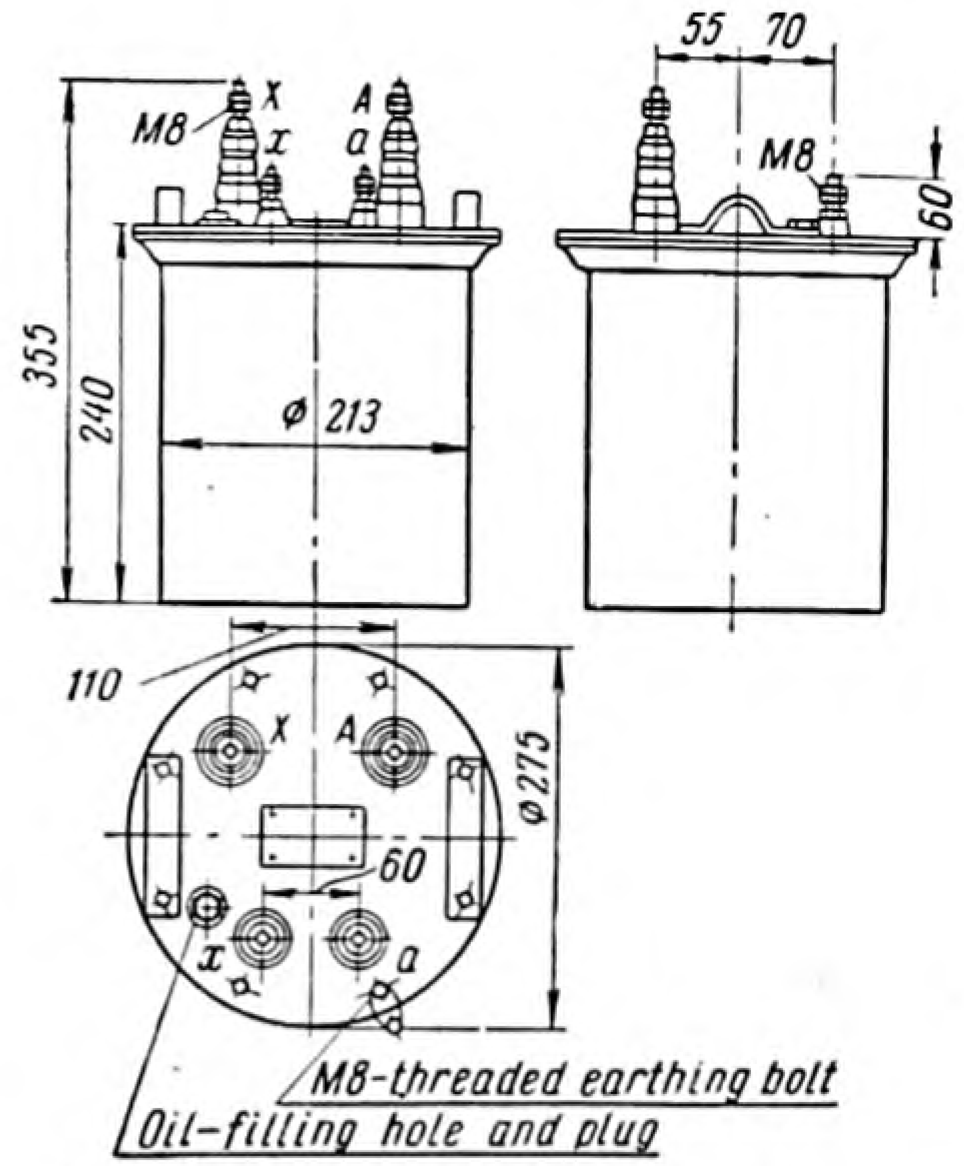


Fig 114 HOM-6 voltage transformer

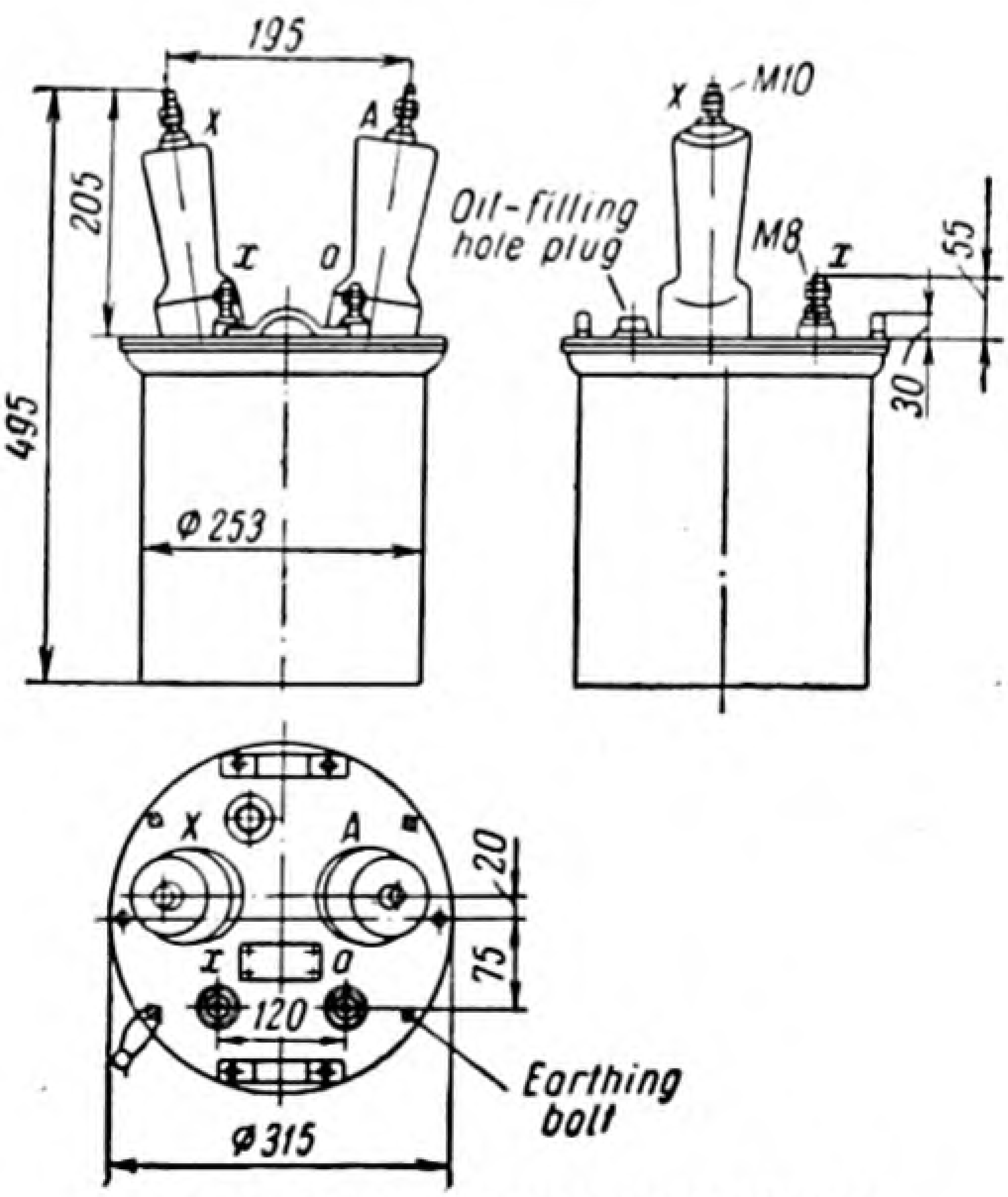


Fig. 115. **HOM-10 voltage transformer**

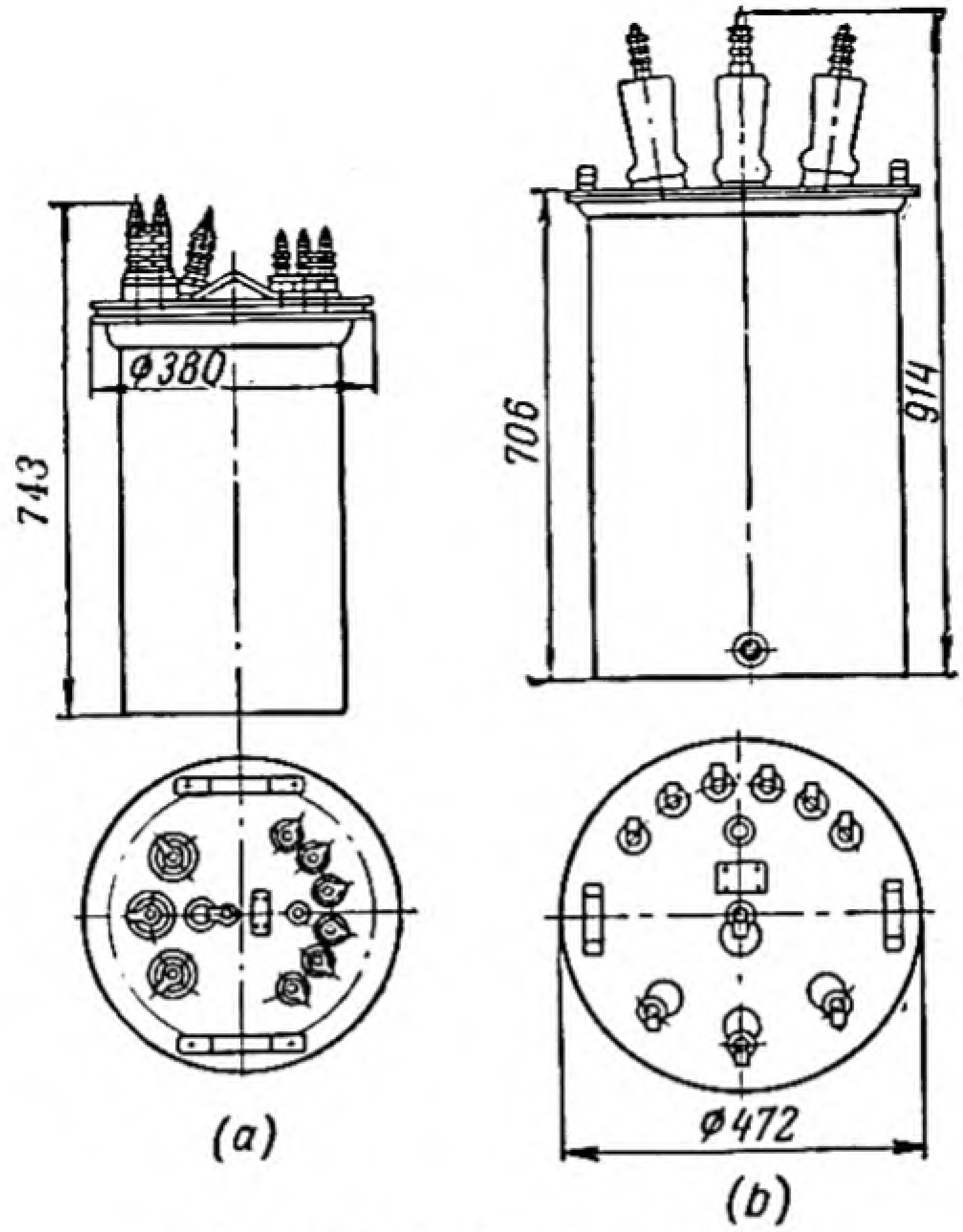


Fig. 116. Voltage transformers:
a—НТМИ-6; *b*—НТМИ-10

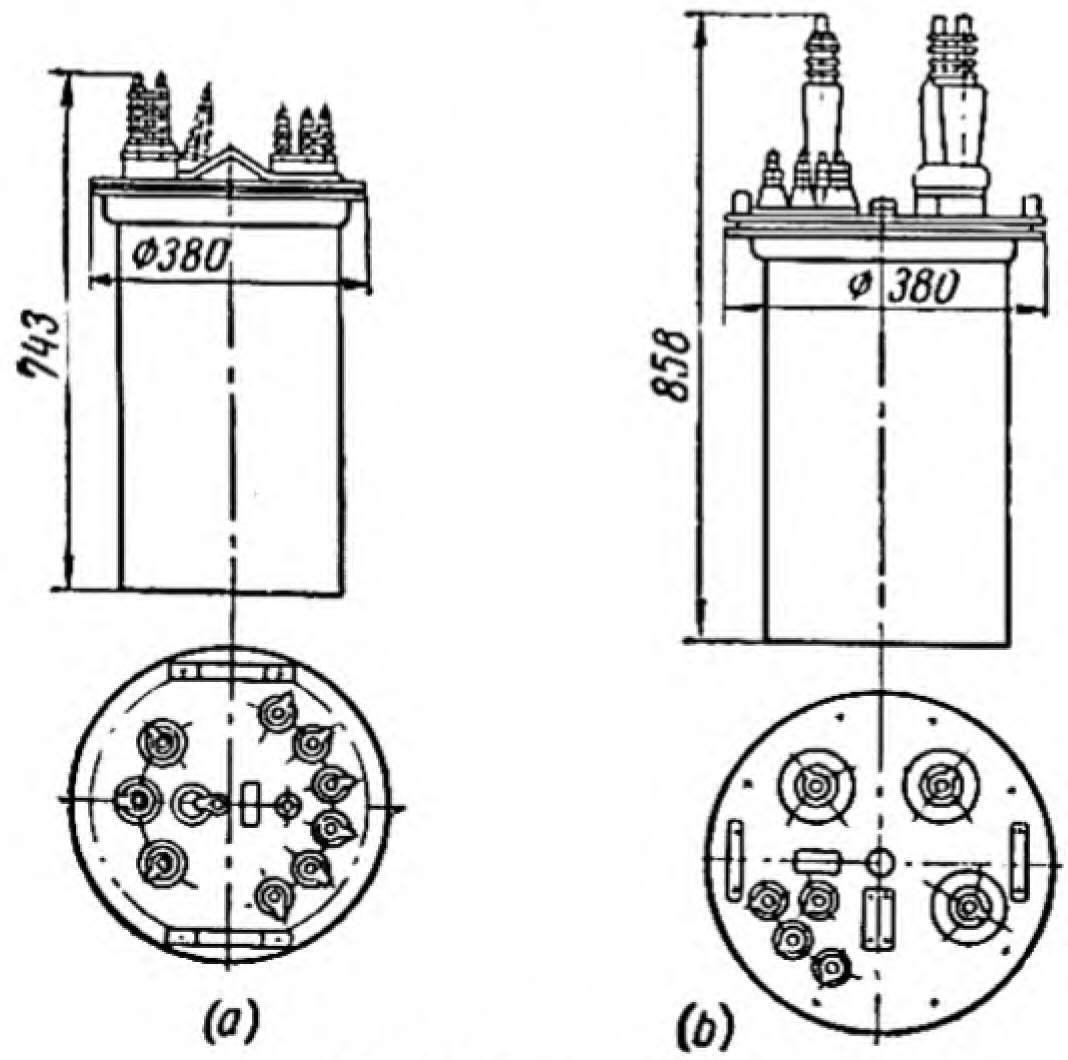


Fig. 117. Voltage transformers:
a—НТМК-6; *b*—НТМК-10

sistance, determination of the polarity of the high-voltage and low-voltage windings, and the ratio.

In addition, since voltage transformers are of the oil-immersed type, oil samples are taken for dielectric strength and acidity tests.

The insulation of a voltage transformer is checked with a 1,000-volt megohmmeter for the insulation resistance of the high-voltage and the low-voltage windings relative to the tank and to each other. Fig. 118 illustrates the test circuits used for these measurements.

The requirements which the insulation in voltage transformers must satisfy are the same as those for current transformers.

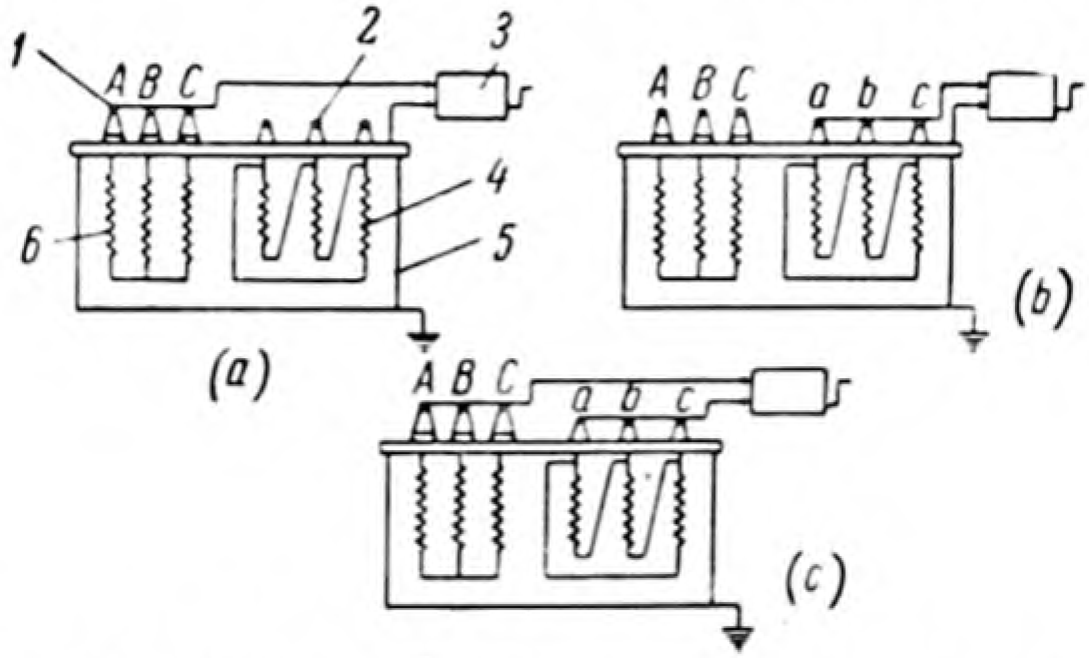


Fig. 118 Voltage transformer insulation test circuits:

a—for measuring insulation resistance of primary relative to earth (tank): *1*—primary terminals; *2*—secondary terminals; *3*— megohmmeter; *4*—secondary; *5*—tank; *6*—primary; *b*—for measuring insulation resistance of secondary relative to earth: *c*—for measuring insulation resistance between primary and secondary

The dielectric strength of voltage transformer insulation is tested using the same circuit employed for power transformers (see Fig. 300).

The absolute value of the insulation resistance of the high-voltage windings is not specified because it sometimes does not give a correct idea of the actual condition of the insulation. More accurately the condition of the insulation can be assessed on the basis of the so-called absorption ratio. This is the ratio of the insulation resistance measured when cranking the tester for 60 seconds to that measured when cranking the tester for 15 seconds. The absorption ratio, k_{abs}, should normally range from 1.25 to 1.30

A lower absorption ratio indicates that moisture is present in the transformer windings and the transformer needs drying out. That a transformer needs drying may be suggested by comparing its insulation resistance with the manufacturer's data. If the insulation resistance has dropped more than 40 per cent, the transformer should be dried out. The same is true when it is discovered that the

transformer oil contains moisture, or if it is known that the insulating parts have been out of the oil for a considerable period of time.

Voltage transformers can be dried out by means of short-circuit currents. More frequently, however, they are dried out by the iron-loss method with the transformer left in its tank emptied of all oil, using the circuit illustrated in Fig. 119. Data for drying-out by this method are listed in Table 13.

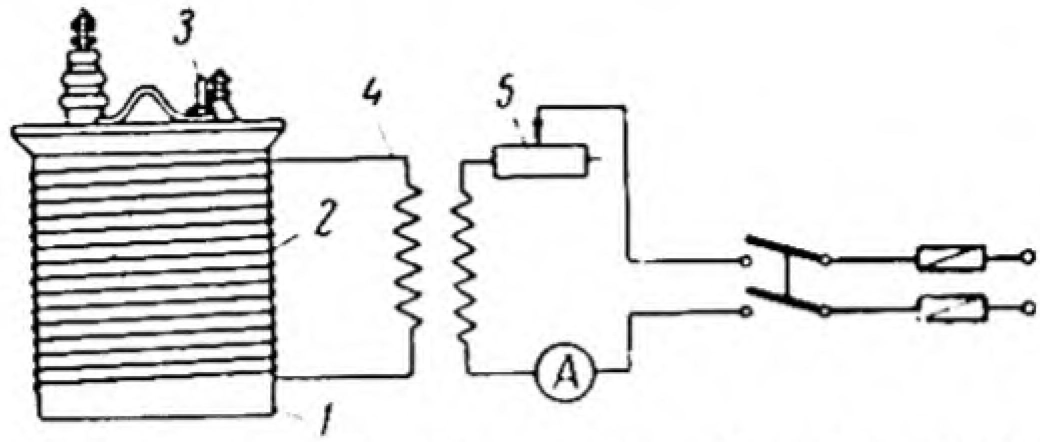


Fig. 119. Circuit for drying out voltage transformers by the iron-losses method:

1—steel tank; 2—magnetising winding; 3—thermometer, 4—220/12-volt transformer for supply of magnetising winding; 5—rheostat

During the drying process, the bottom and top openings of the tank should be left open to allow the vapour to escape, and the high and low voltage windings should be shorted and earthed.

Table 13

Data for Drying Out of Voltage Transformers by the Iron-loss Method

Type of transformer	Characteristics of magnetising coil					Duration of drying period, hr	Max temp. in tank, °C
	supply voltage, v	current, a	turns	conductor size, mm²	length of conductor, m		
HOM-6	12 50	30-40 10-15	24 100	6 4	32 130	24 to 36	100 to 105
HTMK-6	12 50	35-60 10-20	24 82	10 4	34 135	24 to 36	100 to 105

Terminal polarity is checked by using the circuit shown in Fig. 120. A d-c voltage from 2 to 4 volts is applied to the high-voltage winding and an indicating instrument is connected in the low-voltage winding. When the supply circuit is completed, the pointer should swing to the right if the polarity is properly marked. If not, the markings on the winding terminals should be interchanged.

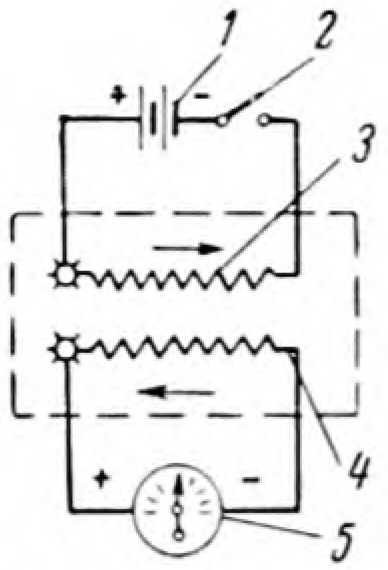


Fig. 120. Polarity checking circuit:

1—dry cell; 2—switch; 3 — primary; 4 — secondary; 5—galvanometer

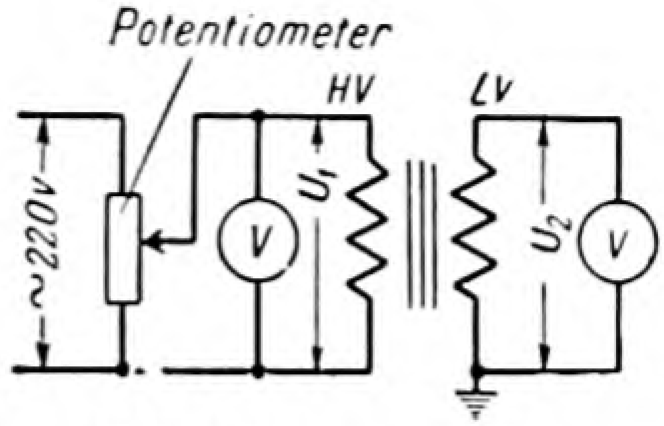


Fig. 121. Voltage transformer ratio test circuit

Three-phase voltage transformers are checked for polarity by connecting a source of voltage to the high-voltage terminals in turn: first, say, to C and B, and the instrument to the low-voltage terminals c and b; then to A and B, and to a and b, etc. If in all three cases the instrument pointer swings to the right, the leads are marked correctly. Otherwise the markings should be changed.

The transformation ratio of a voltage transformer is checked in the test circuit shown in Fig. 121 and is calculated from the formula

$$r_v = \frac{U_1}{U_2}.$$

Mounting of voltage transformers. The mounting of voltage transformers involves three fundamental operations:

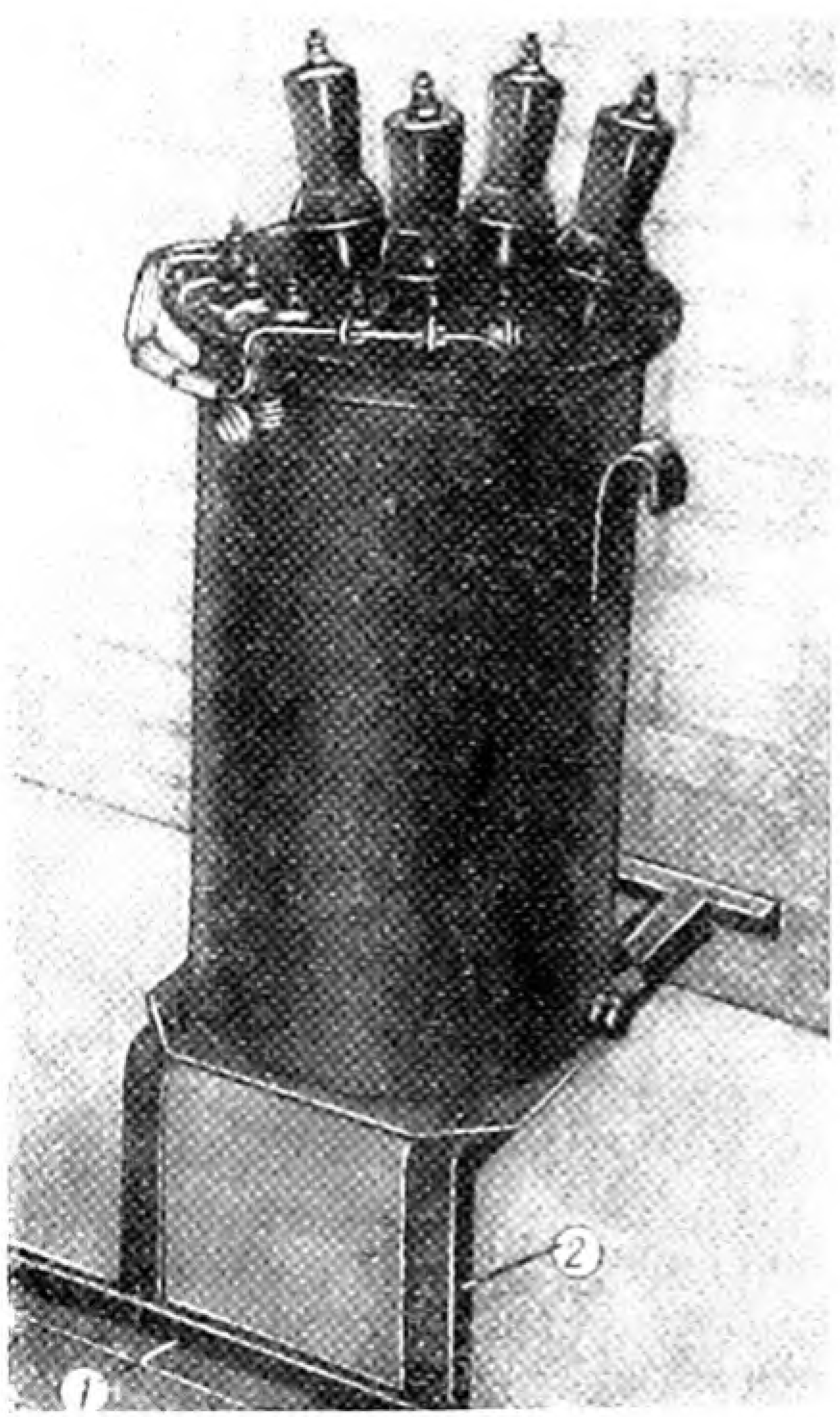


Fig. 122. НТМИ-10 voltage transformer set on a L-shaped metal support of steel angles:

1—foot angle; 2—support frame

(1) placing of a metal support;
(2) lifting and setting of the voltage transformer on the support;
(3) earthing.

Metal supports for voltage transformers differ widely in construction. Fig. 122 shows a metal support for an HTMII-10 voltage transformer made from angles and placed directly on the cell floor. The lower angle *1* and the lower ends of the uprights *2* are grouted in.

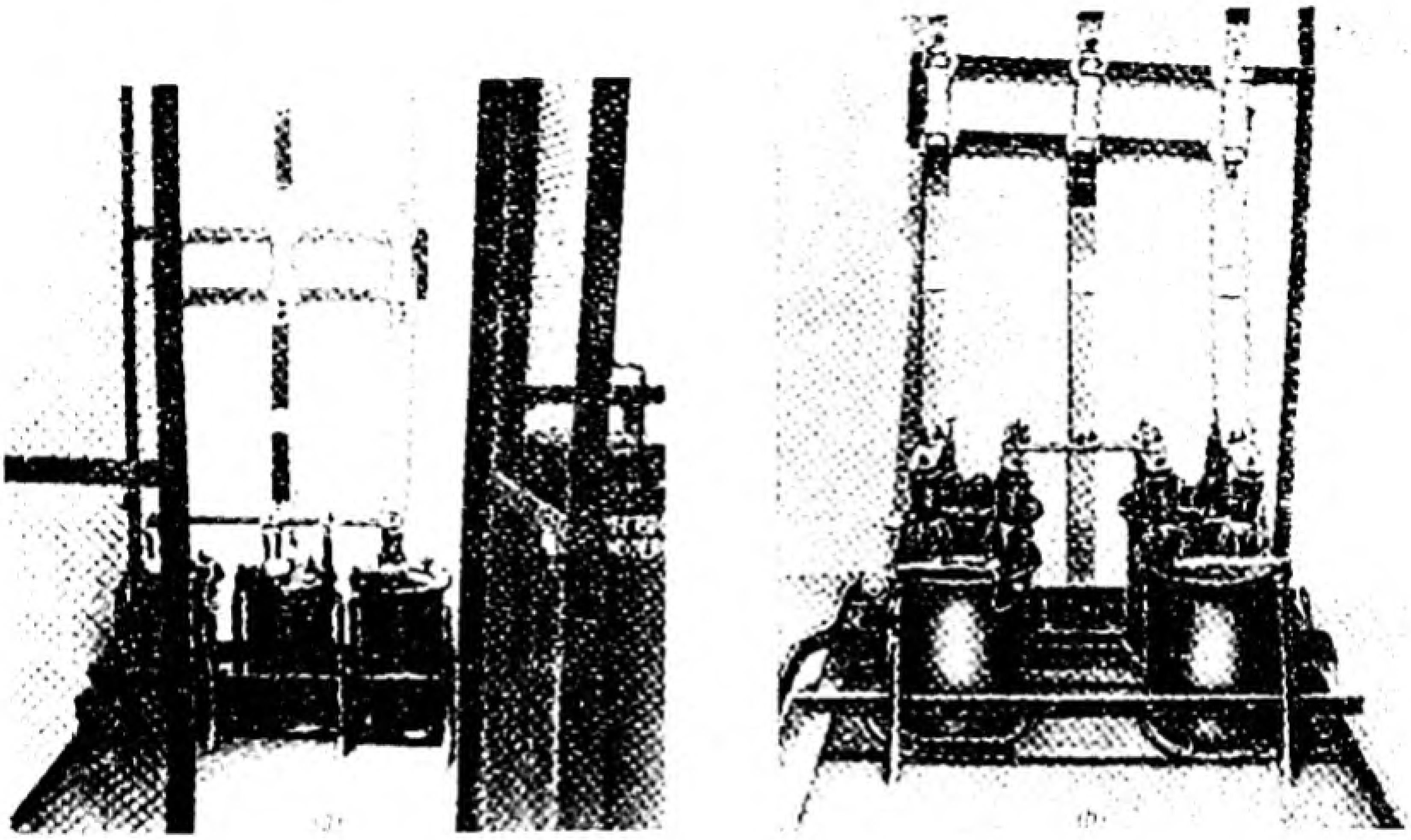


Fig. 123. HOM-10 voltage transformers mounted in a station switchgear cell: *a*—three-transformer installation; *b*—four-transformer installation

Fig. 123*a* and *b*, exemplifies installation of three and four HOM-10 voltage transformers on angle metal supports in an indoor switchgear compartment.

Voltage transformers are usually lifted in position by hand. During mounting, their high-voltage terminals should be shorted and earthed, and their low-voltage terminals should be disconnected from wires, as any accidental or unintentional contact of these wires with a live lighting or power circuit will cause a high voltage to appear across the high-voltage terminals.

Voltage transformers should be set up so that their oil drains and oil-level gauges face the aisle.

Prior to applying the voltage to a transformer, the pressboard washer should be removed from under the oil-hole bolt to provide communication with the ambient atmosphere.

When mounting three-phase voltage transformers, the terminal marked A should be connected to the yellow-coloured bus, the terminal B to the green-coloured bus and the terminal C to the red-coloured bus.

The terminal A on single-phase voltage transformers may be connected to any one of the three-phase buses. The terminal marked X should be earthed. When three single-phase voltage transformers are mounted in a bank, all the X-marked terminals should be made common by a bus and earthed. When two voltage transformers are mounted and open-delta connected, the operating phase on the low-voltage side should be earthed only when it is required by the design.

Each voltage transformer tank must be connected to the earthing bus by an individual busbar.

Problem. Write up the mounting of an НМТИ-10 voltage transformer in a switchgear cell according to Fig. 122. Include in the description a sketch of the metal support.

19. Mounting of High-voltage Fuses

Indoor substations use ПК fuses (the letter П standing for "fuse", and the letter К, "quartz-sand filled") for power circuit protection,

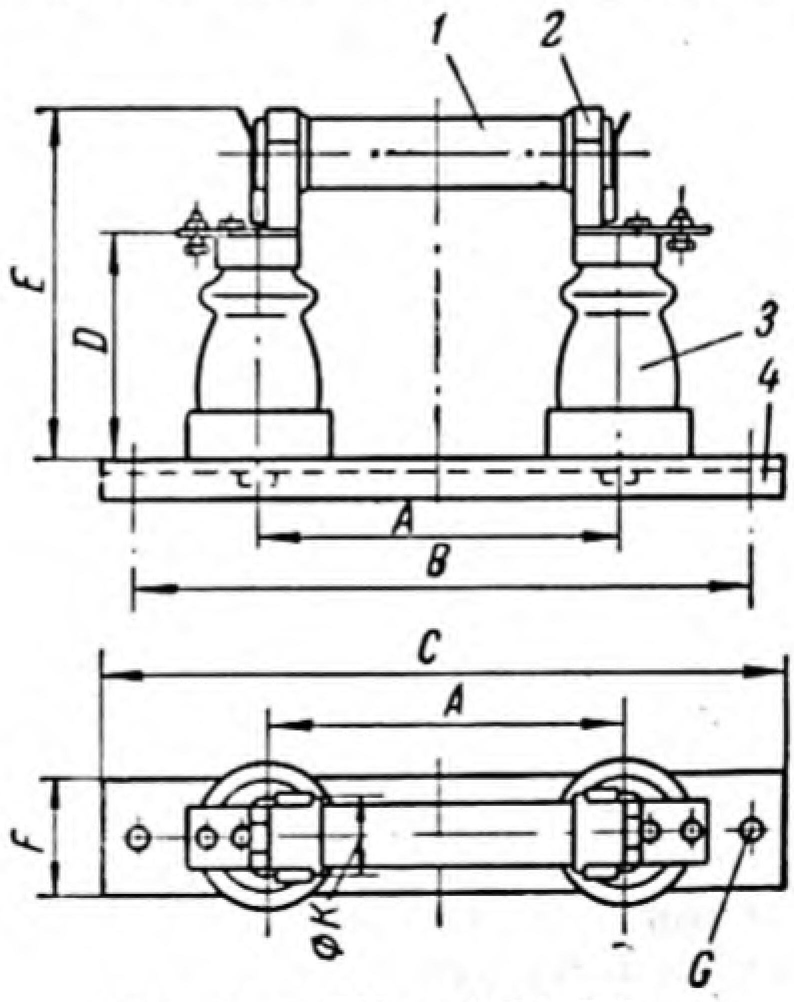


Fig. 124. ПК and ПКТ fuses:
1—case; *2*—clip jaws; *3*—insulator; *4*—base

and ПКТ fuses (T meaning "transformer") for voltage transformer protection (Fig. 124).

The principal installation dimensions and weight of ПК and ПКТ fuses are listed in Table 14.

Table 14

Dimensions and Weight of ПК and ПКТ Fuses

Type of fuse	Dimensions (Fig. 124), mm							Weight with case, without base, kg
	A	*B*	*C*	*D*	*E*	*F*	*G*	
ПК-6/150	365	505	550	170	285	80	14	13
ПК-10/50	465	600	650	195	310	80	14	8.76
ПК-35/20	625	825	865	395	470	150	18	20.2
ПКТ-10	215	400	450	175	250	80	14	4.5

Initial inspection of fuses. The porcelain parts of high-voltage fuses must satisfy the same requirements as high-voltage support insulators.

The clip jaws must be resilient and clamp the fuse case all the way round the circumference. The fuse case should be hermetically sealed. The quartz-sand filling must be sufficiently compact; when the case is shaken, no sound of the sand moving in it should be heard.

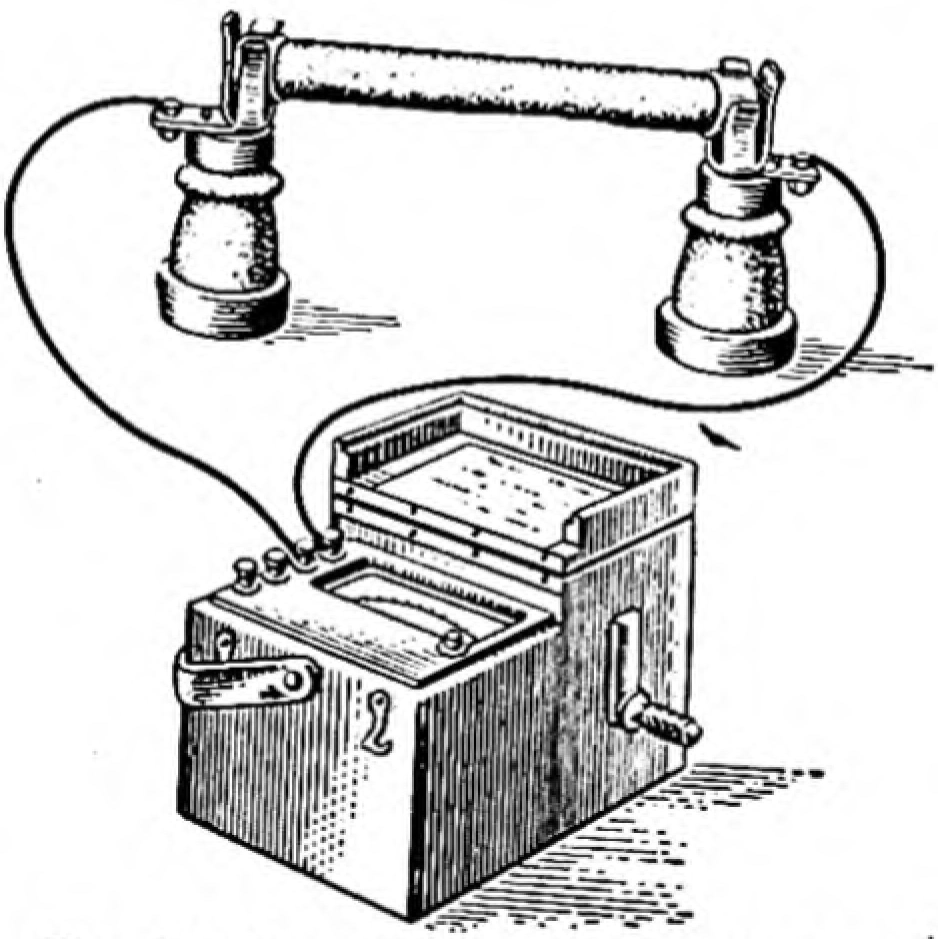


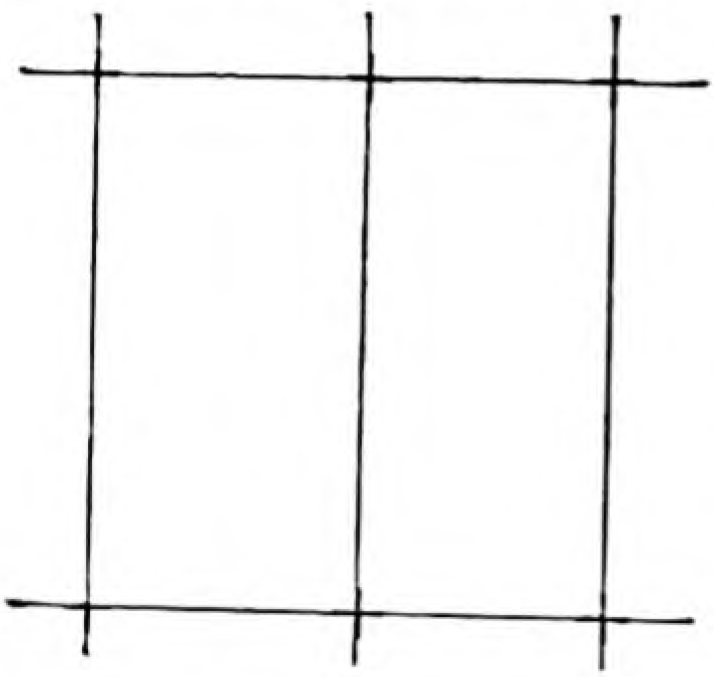
Fig. 125. Fuse link continuity checking

In the case of ПК fuses the blown-fuse indicator should also be checked by pressing its armature. If the indicator is good, the

armature will deflect a little and swing back. Fuse links must also be checked for continuity with a megohmmeter (Fig. 125).

Mounting of fuses. The mounting of fuses begins with marking out their positions. This is illustrated in Fig. 126*a*.

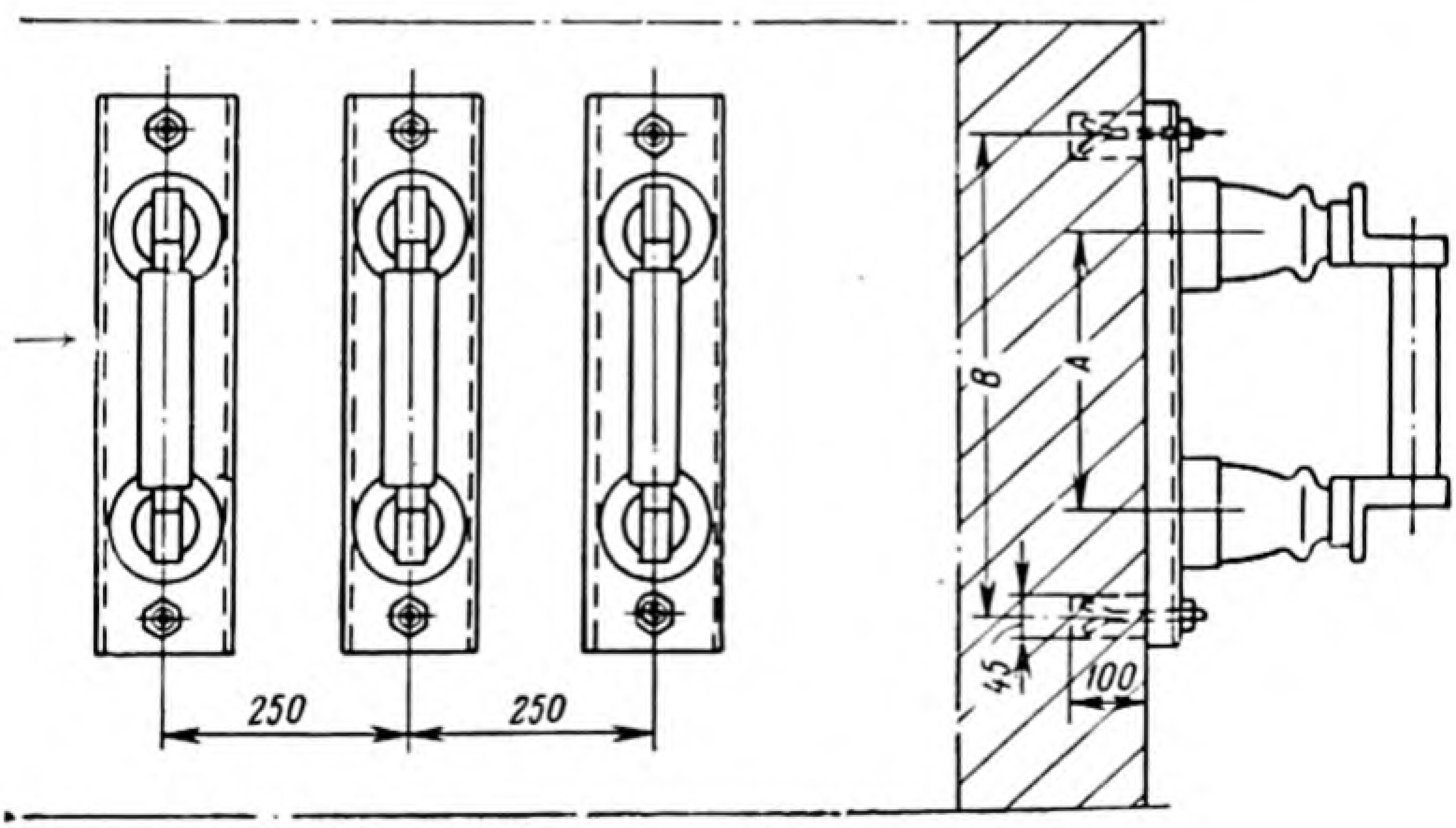
Fuses may be mounted by directly fixing their bases on a brickwork or concrete wall with anchor studs (Fig. 126*b*), on a special metal support (Fig. 127), or on the metal framework of the switchgear cell.



(a)

The surface of the support should be levelled so that the upper and lower fuse clips and the blade contacts are on a common vertical line. Failure to observe this will impair contact between the fuse and clips and may lead to contact pitting.

Fuses, as a rule, are mounted in a plumb position. ПК fuses should be mounted so that their blown-fuse indicators point downward.

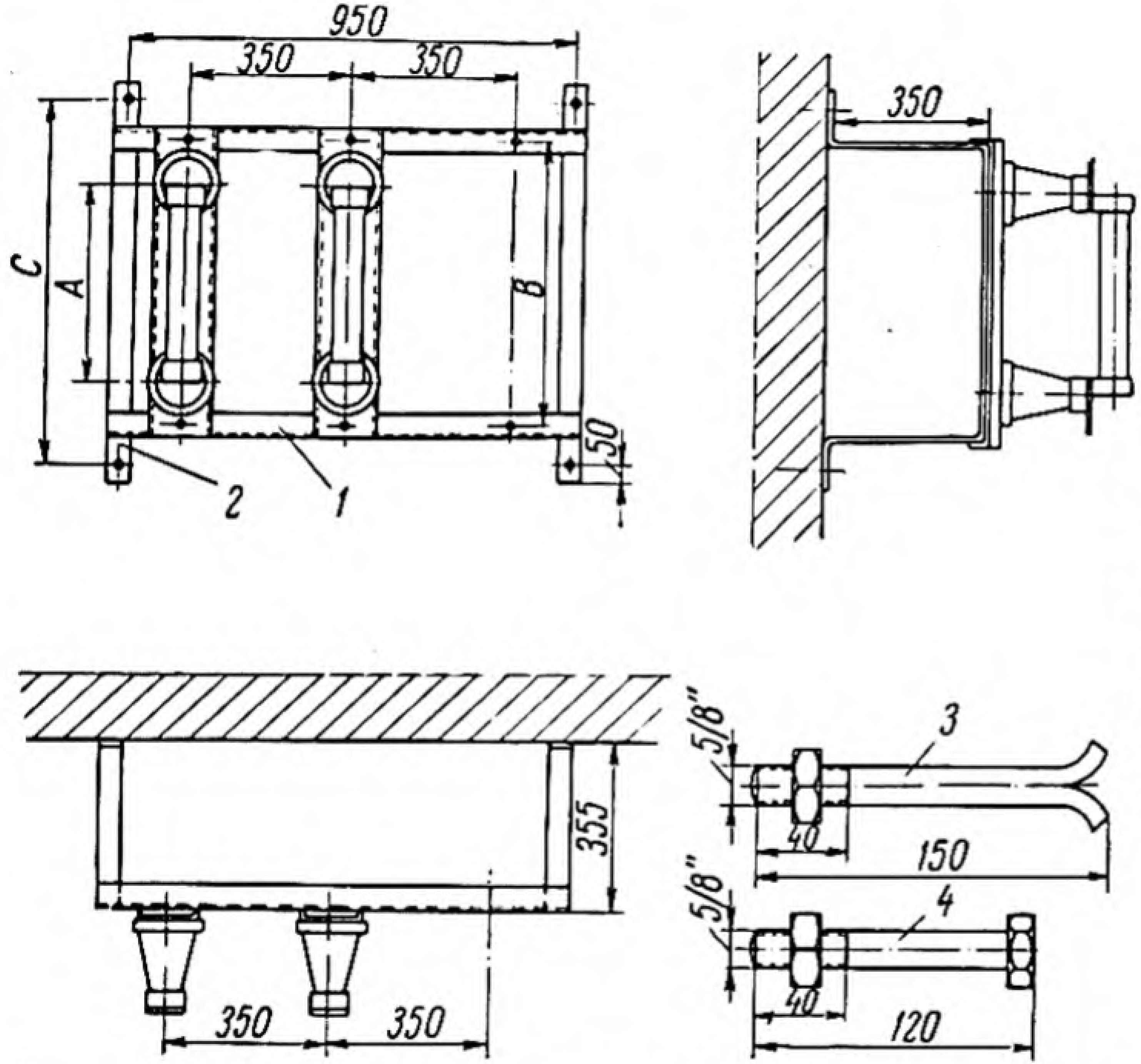


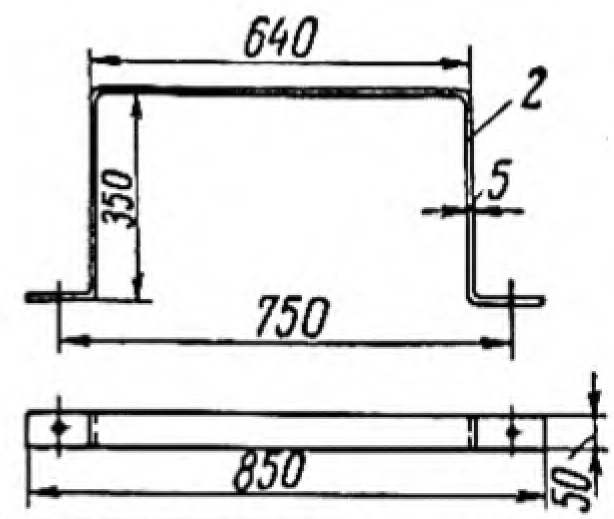
(b)

Fig. 126. Phase-to-phase spacing of ПК fuses:
a—layout lines; *b*—mounted fuses

The surface of fuse supports is checked for verticality by means of a plumb-bob.

Problem. Write up an operation sequence for mounting a bank of three high-voltage ПК-6/100 fuses on a concrete surface.





Specification		
Item No.	N a m e	Q'ty
1	Steel angle 50×50×5 l=1000	2
2	Steel strip 50×5 l=1550	2
3	5/8"×150 mm anchor stud for fixing framework to brick wall	4
4	5/8"×120 mm bolt, with nut and washer, for mounting framework on concrete wall	4

	A	B	C
ПК-6/20	320	400	550
ПК-8/100	365	500	650
ПК-10/20	420	500	750
ПК10/50 from 30 to 50	465	600	750

Fig. 127. Metal support frame for ПК fuses

20 Mounting of Cast-in-concrete Reactors

Indoor substations use air-core reactors in which the coils are cast-in-concrete columns or separators. The principal dimensions of cast-in-concrete reactors can be seen in Fig. 128 and Table 15.

Inspection of cast-in-concrete reactors prior to installation. First the concrete columns are examined for possible cracks and chipped spots, the reactor windings for deformed turns, the insulation for damage. Furthermore, there should be no foreign objects between the turns, and the protective varnish coating of the concrete columns should not be damaged. Also, it is important to make sure that the bolts are reliably embedded in the concrete.

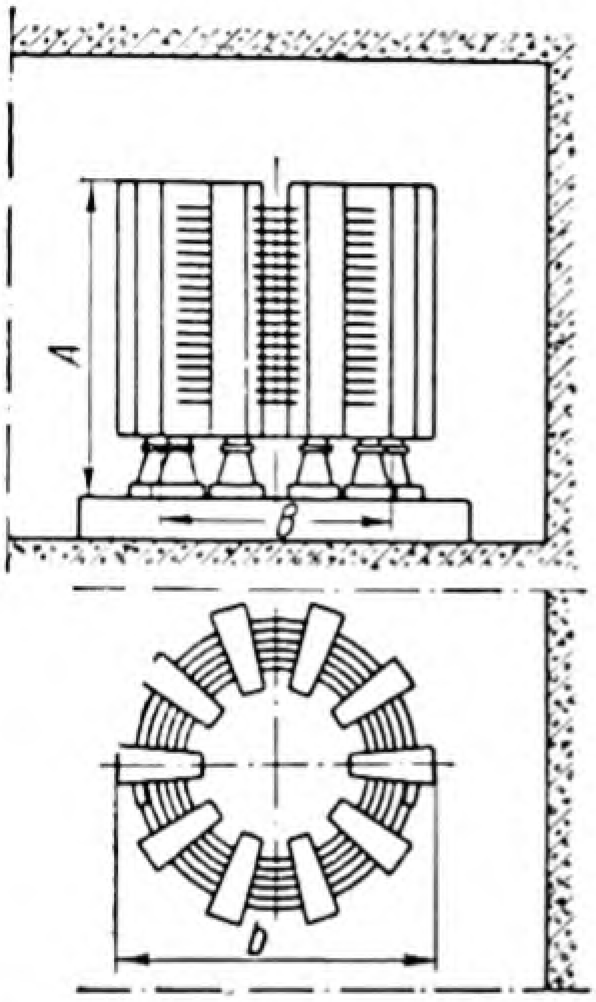


Fig. 128. Installation dimensions of a cast-in-concrete reactor

Damaged reactor columns may be repaired in workshops or, if necessary, directly on the installation site. For this purpose shuttering made from smooth-planed boards lightly coated with petroleum jelly or grease on the inside is put on the damaged column to be repaired.

The concrete used for the repair consists of one part of Grade 400 to 600 cement, one part of washed and dried quartz sand, one part of washed gravel (mainly consisting of granite) having a grain size of up to 5 mm, and 40 to 60 per cent of water by cement weight.

This concrete has a setting time of 48 hours, after which the shuttering may be removed. Full design strength is reached 25 to

Table 15

Principal Dimensions and Weight of Several Cast-in-concrete Reactors

Reactor type designation	Dimensions according to Fig. 128, mm			Number of insulators	Type of insulator	Weight per phase, kg
	A	*b*	*B*			
РБ-6-200-5	995	990	695	10	ОА-6	610
РБ-6-500-10	1,265	1,180	885	14	ОА-6	1,173
РБ-6-1500-10	1,220	1,260	895	12	ОВ-6	1,553
РБ-10-200-8	1,155	1,175	845	12	ОА-10	834
РБ-10-1500-8	1,295	1,410	1,045	12	ОД-10	1,808

30 days after the concrete has been placed, after which time the reactor must always be dried out and baked (see Table 16).

Table 16

Air Temperature and Duration of Heating in Oven for Each Drying Operation

Sequence Nos.	Operation	Air temp. in drying oven, °C	Duration of operation, hr
1	Gradual warm-up of reactor	90 to 100	4 to 6
2	Heating of reactor (drying-out)	100 to 110	12 to 24
3	Measurement of reactor insulation resistance to determine end of dry-out	100 to 110	6 to 8
4	Gradual cooling of reactor	Up to 65	3 to 7
5	Application of linseed drying oil or varnish coating to the concrete	65	0.5 to 1
6	Re-heating of reactor	100 to 110	2 to 3
7	First baking of varnish coating	110	6 to 8
8	Operations (4), (5) and (6)	65-95-110	7 to 10
9	Second baking of varnish coating	110	6 to 8
10	Gradual cooling of reactor	Down to 5-10° above ambient temp.	6 to 8

Deformed turns should be carefully straightened and their damaged insulation restored with a tape serving impregnated with an insulating varnish.

The reactor post insulators should meet the usual requirements for post insulators (refer to Sec. 8).

The insulation resistance of the reactor is measured between the winding and earth with a 1,000-volt tester (Fig. 129*a*) and for the 10-kv class of reactors should normally be not less than 10 to 15 megohms.

At the same time, the insulation resistance is measured between the winding and the concrete (Fig. 129*b*). The requirement in this case is one megohm per kilovolt of rating.

Using the circuit illustrated in Fig. 129*c*, the insulation resistance between the phase coils is measured. Normally, it should be comparable with that measured between the winding and earth.

The reactor insulation is also subjected to a proof voltage test. For 6-kv reactors the test voltage is 32 kv, and, for 10-kv reactors, 42 kv at commercial frequency (50 cps) in both cases, and applied for one minute.

Reactors which fail to meet the above requirements should be dried out. For drying, the reactor is placed in an oven through which hot air is blown, or, which is a better method, in a vacuum chamber.

If reactors are found to be moist, coats of linseed drying oil or varnish should be applied and baked at the end of the drying-out process.

Table 16 gives the air temperature to be maintained in a drying chamber and the duration of each operation involved in the drying-out process using an air blower.

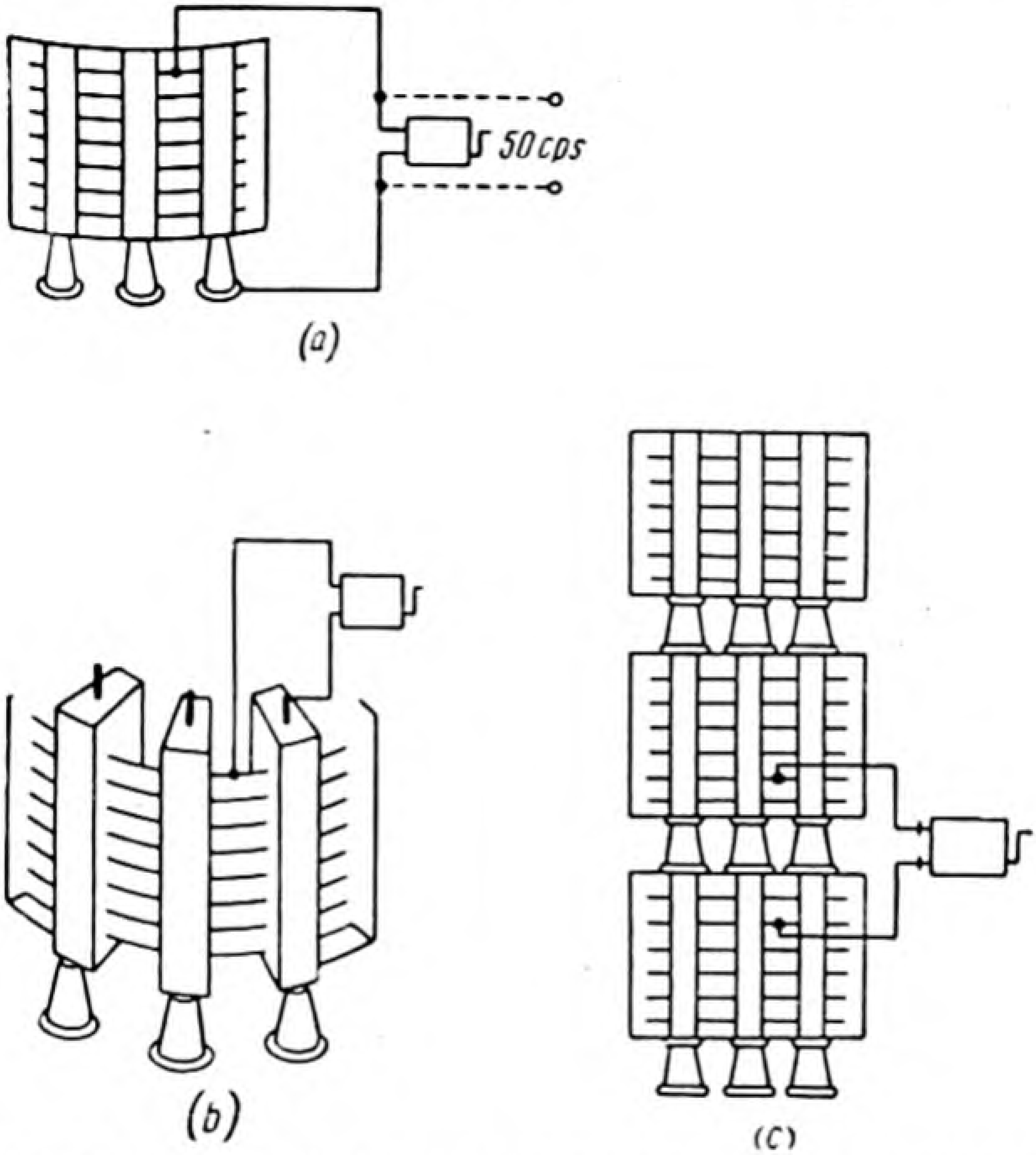


Fig. 129. **Reactor insulation resistance testing circuit arrangements:**
a— for insulation resistance of coil relative to earth; *b*—insulation resistance between coil and concrete; *c*—between coils of each phase

The drying chamber is built of fireproof material and lagged on the inside with a layer of thermal insulation (asbestos, glass-wool matting) 10 to 15 mm thick. The top and bottom of the chamber should have ventilating openings equipped with slide valves for temperature control. A sectional view of a drying chamber, air blower and air heater is given in Fig. 130 in diagrammatic form.

When the insulation resistance of a reactor is only slightly below the standard requirement, drying-out may sometimes be dispensed with on the assumption that the insulation level will rise to normal during operation due to the heat generated by the load current.

Mounting of reactors. The three phases of a reactor bank may be arranged either vertically (Fig. 131), or horizontally. The vertical arrangement is used more frequently.

The reactors are moved to the switchgear cell on a truck or on rollers. The latter method is practised quite widely, but a heavy rope must be wound over the concrete parts to avoid any damage to them.

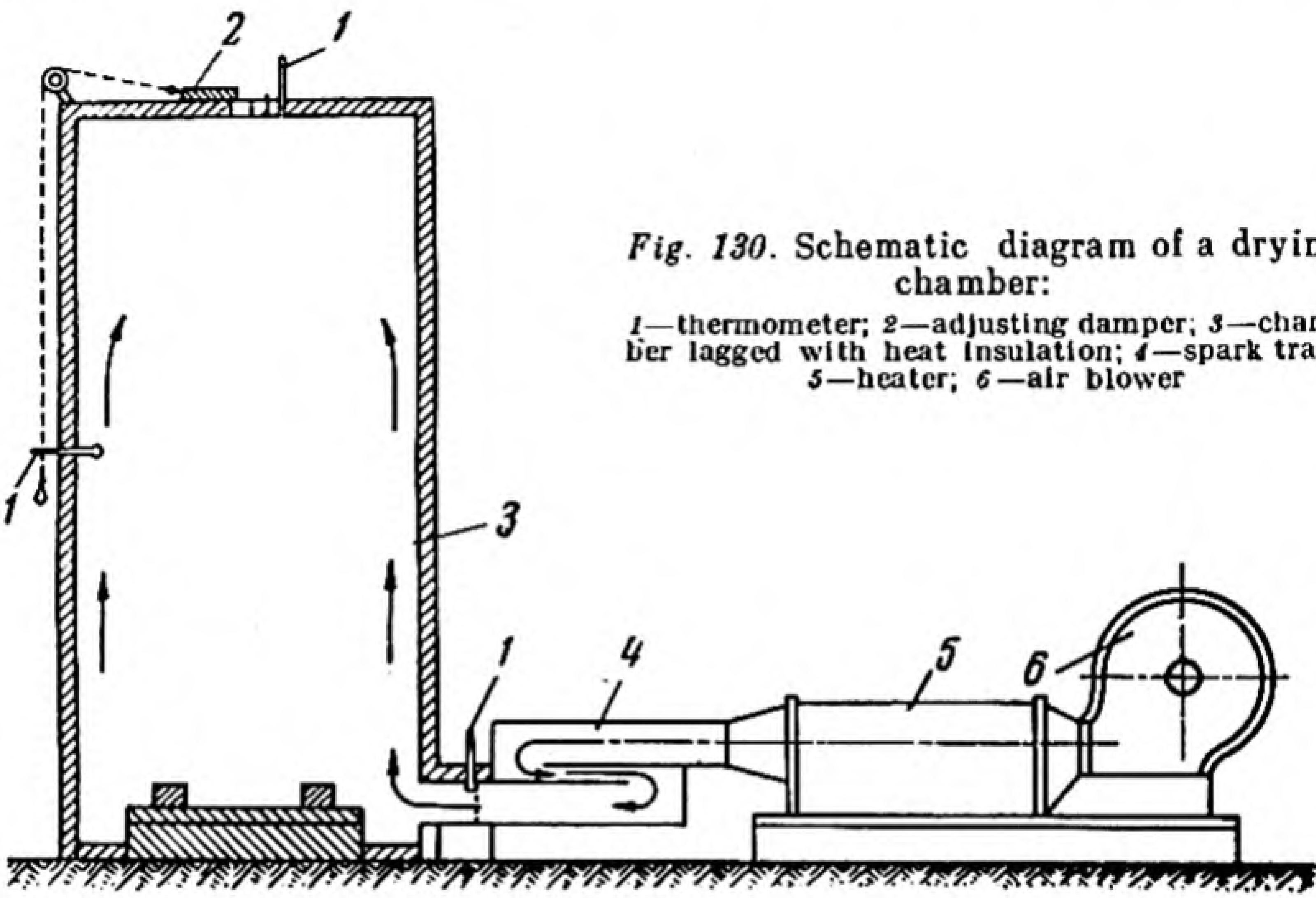


Fig. 130. Schematic diagram of a drying chamber:

1—thermometer; *2*—adjusting damper; *3*—chamber lagged with heat insulation; *4*—spark trap; *5*—heater; *6*—air blower

Foundation slabs for cast-in-concrete reactors (Fig. 132 *a* and *b*) are usually provided by builders to approved drawings.

The top-phase reactor is lifted with a worm-gear hoist (see Fig. 11) and a channel placed across the cell at the top. Recently wider use has been made of an electric hoist instead of a hand-operated worm-gear hoist. The post insulators are attached to the bottom of the upper-phase reactor; the middle-phase reactor is next moved into the cell, the upper reactor is lowered on it, and both reactors are joined together. After this, the entire assembly is lifted up and post insulators are attached to the bottom of the middle-phase reactor.

Next the lower-phase reactor is moved into the cell, and the upper- and middle-phase reactor assembly is seated on it and joined to form one unit. The three phases may now be lifted by a worm-gear hoist or an electric hoist and post insulators may be attached to the bottom of the lower-phase reactor, after which the entire assembly may be lowered into place and secured on the foundation.

The reactors joined together should be checked with a batten and level for horizontality and with a plumb-bob for verticality. When necessary steel shims may be inserted under the bases of the post insulators.

When the upper-phase reactor is placed on the middle-phase reactor, and the middle-phase reactor on the lower-phase reactor, cardboard pads 2 to 3 mm thick are placed on the caps and under

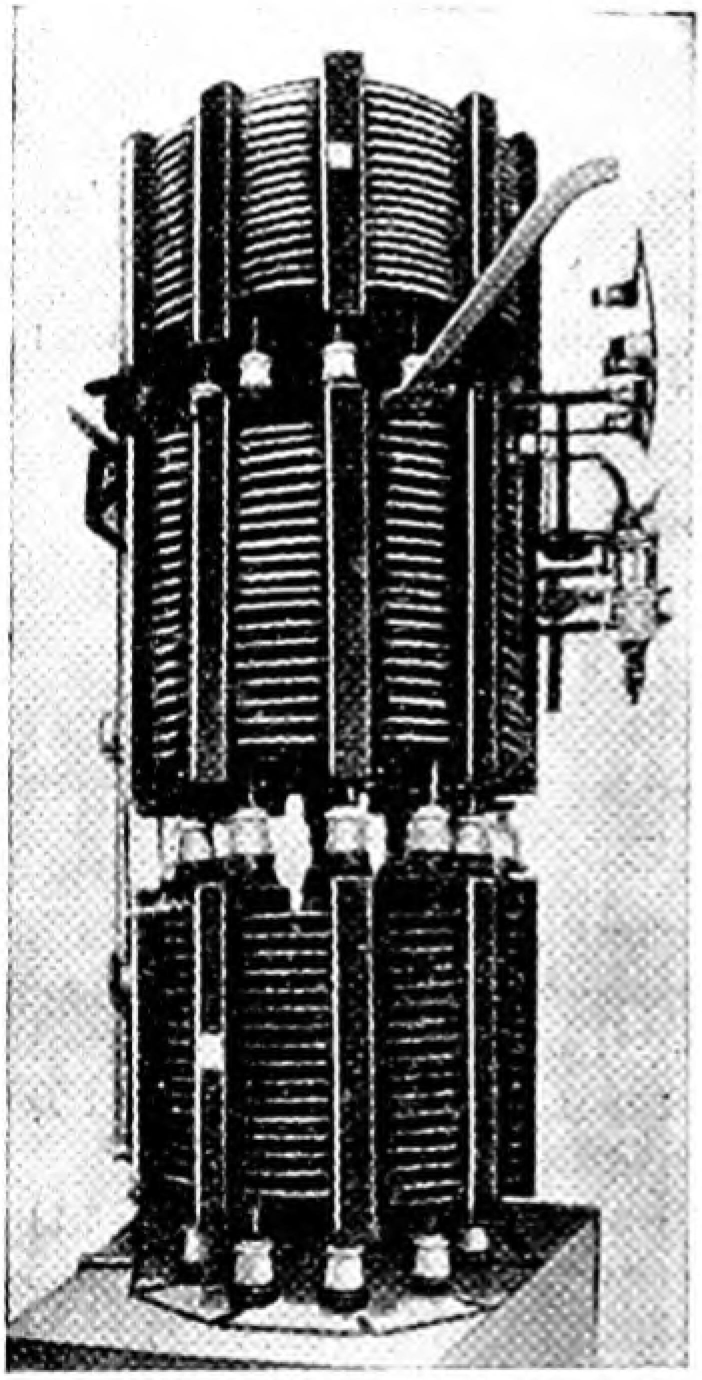


Fig. 131. Vertical arrangement of cast-in-concrete reactors

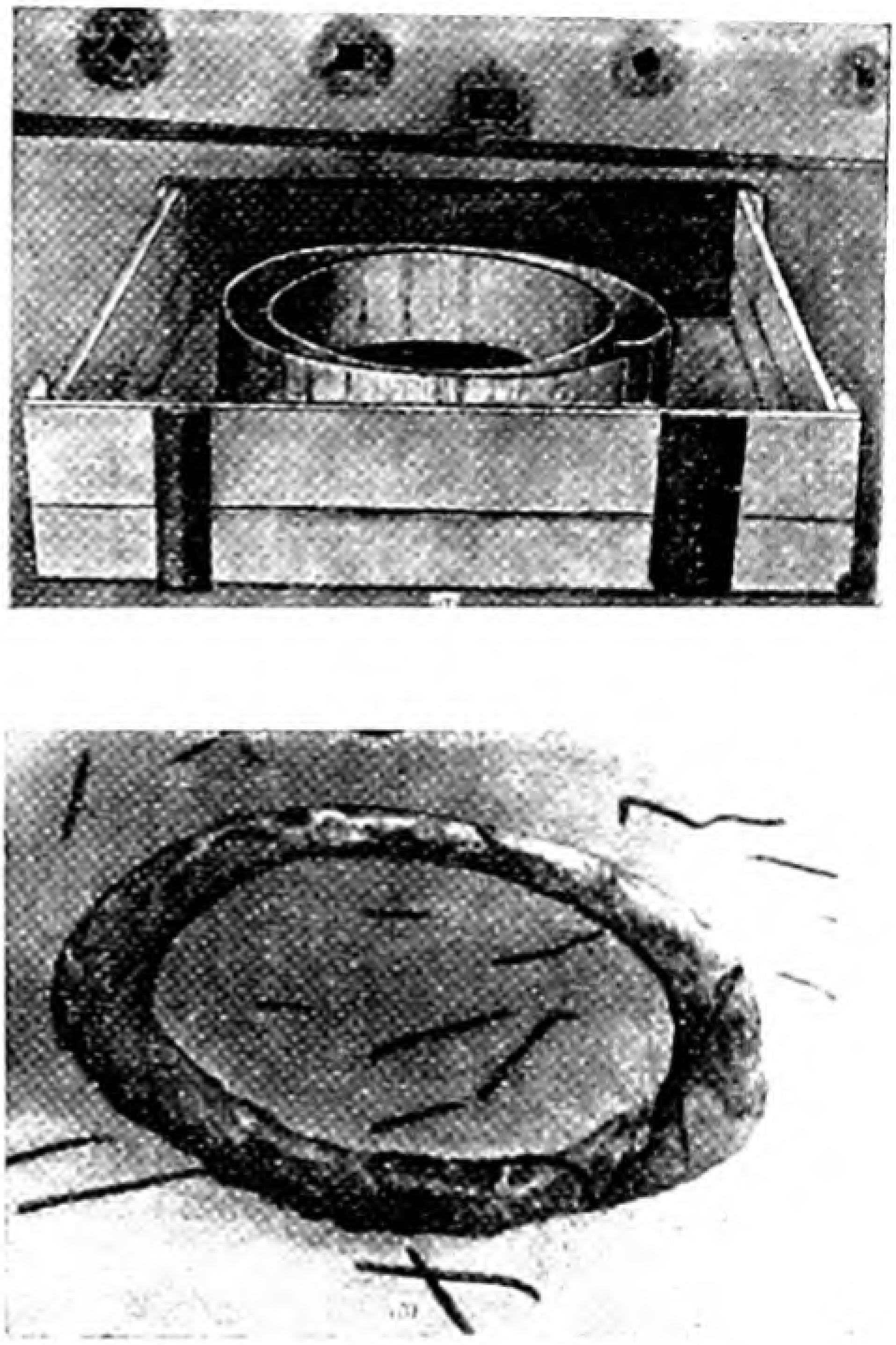


Fig. 132. Foundation slab for a reactor: *a*—shuttering (form) set up for pouring; *b*—ready foundation slab

the bases of insulators. These pads serve to moderate the shocks when short-circuit currents flow through the reactor.

After a reactor has been mounted the flanges of the lower post insulators are connected to a 40×4 mm earthing busbar so that it does not form a closed turn and a break is left between the flanges of any two insulators. A closed turn would result in eddy currents and accompanying heating.

The earthing circuit of the post insulators is then connected to the earthing bus.

Of late there has been a tendency to lay reactor foundations in the process of erection rather than beforehand.

By this method, after the three phases of a reactor bank have been joined together and lifted, the assembly is lowered on a masonry ring one half-brick thick so that the masonry ring runs through the centres of the insulator bases on the lower-phase reactor and the fixing bolts overhang on both sides (oval-base insulators are used). Then cement mortar is poured around the reactor base within the shuttering bounding the slab area until level with the lower edge of the insulator bases.

This method greatly simplifies bolt-hole layout and cuts down time requirements.

Problem. Write up an operation sequence for mounting a cast-in-concrete reactor in an indoor switchgear cell of the 6-10-kv class.

21. Mounting of Valve-type Lightning Arresters

Lightning arresters are safety devices designed to protect electrical equipment from overvoltages due to atmospheric disturbances. Indoor switchgear uses valve-type suspension arresters. The installation dimensions of this type of arrester are given in Fig. 133. A РВП-6 arrester weighs 8 kg, and a РВП-10 arrester, 16.5 kg.

Visual inspection. Before erection, lightning arresters must be inspected for broken porcelain and fittings, and also for missing parts. They should be lightly shaken to make sure that no rattling can be heard from within; otherwise, it is a sign that the internal parts are loose. In such a case, the defective arrester should be sent to a laboratory or a workshop for reassembly.

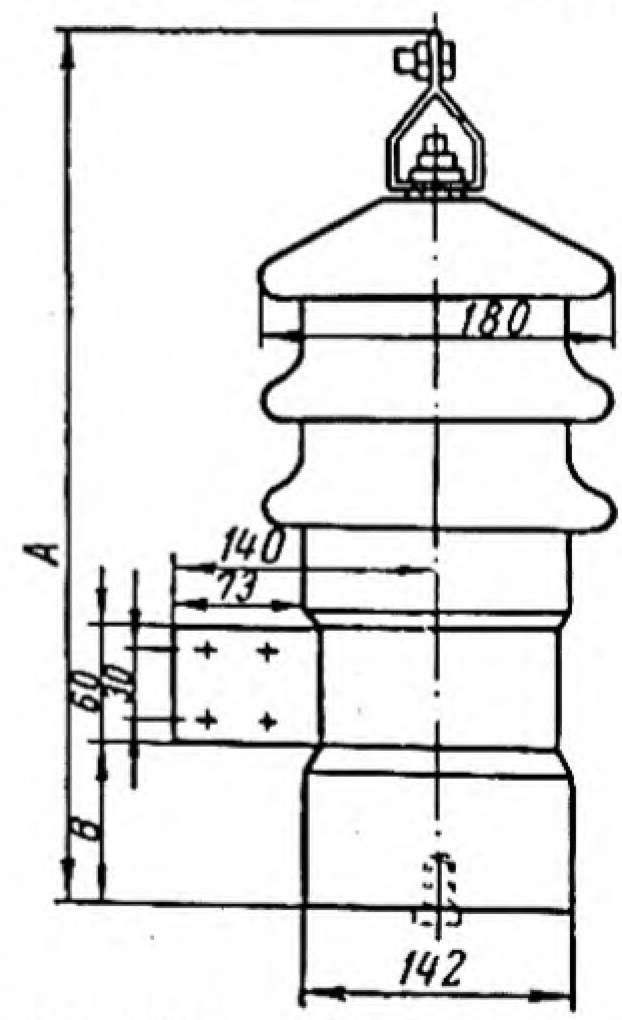


Fig. 133. Installation dimensions of the РВП lightning arrester

Mounting of lightning arresters. Two basic methods are used for mounting the lightning arresters. The first way is to suspend them by the hanger eye and secure with a clip made from 30×3 mm steel strip to prevent the arrester from swinging. More frequently arresters are affixed directly to a metal support by means of a band made from 60×6 mm steel strip (Fig. 134).

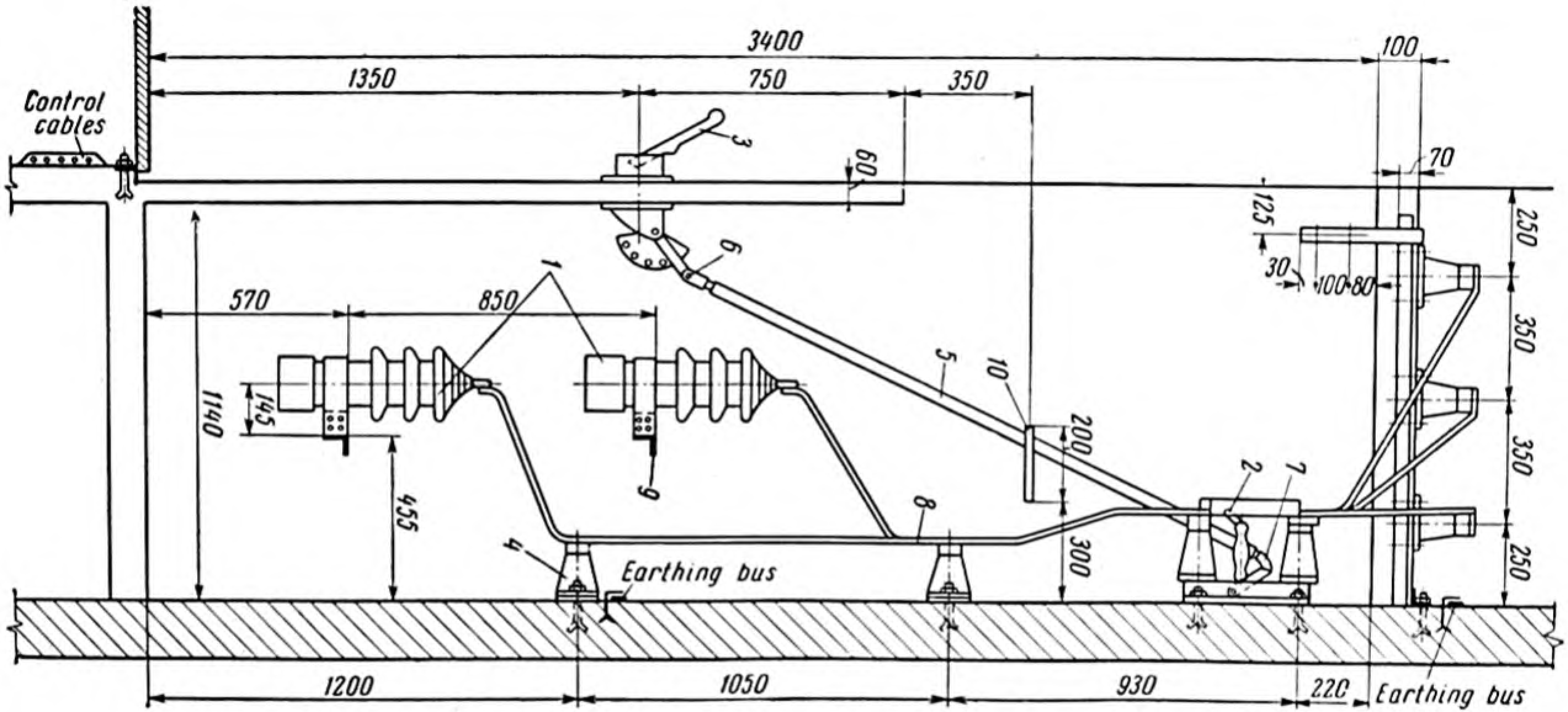


Fig. 134. РВП-10 lightning arresters attached to metal supports in a cell:

1—lightning arrester; *2*—isolator; *3*—operating mechanism; *4*—post insulator; *5*—tie rod; *6* and *7*—clevises; *8*—busbars; *9*—metal support; *10*—safety stirrup

After mounting, each lightning arrester is connected to the earthing bus by a 40×4 mm steel strip. The distance between the earthing bus and the lightning arrester should be as short as practical, so as to keep the resistance of the earth connection to a minimum.

The top contact bolt of the arrester is connected to the respective bus. When connecting a lightning arrester either to a power bus or an earthing bus, great care must be taken that no mechanical stress will be experienced by the relatively weak contacts of the arrester, or they may become loose, the arrester may become air-leaky and break down.

Problem. Write up an operation sequence for mounting a РВП-10 valve-type lightning arrester on a metal support as shown in Fig. 134.

22. Installation of Busbars

Substations for 6-10-kv service mainly employ aluminium busbars of rectangular cross section; to a much lesser extent use is made of copper and steel busbars. Data on the dimensions and weight of some busbars are given in Table 17.

Table 17

Dimensions and Weight of Aluminium and Copper Busbars of Rectangular Cross Section

Busbar material	Dimensions, mm	Weight, kg/m
Hard-drawn aluminium	20×3	0.126
	25×3	0.202
	30×5	0.405
	40×4	0.432
	50×5	0.675
	60×6	0.975
	80×8	1.728
	80×10	2.160
	100×10	2.70
Hard-drawn copper	20×3	0.54
	25×3	0.666
	30×5	1.34
	40×4	1.42
	50×5	2.22
	60×6	3.14
	80×8	5.68
	80×10	7.11
	100×10	8.89

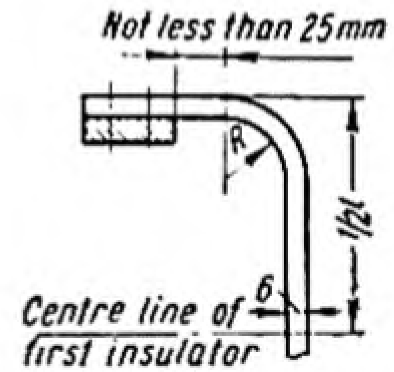
The selection, straightening, cutting, bending, and joining of busbars are described in the sequence chart given below (Table 18).

Table 18

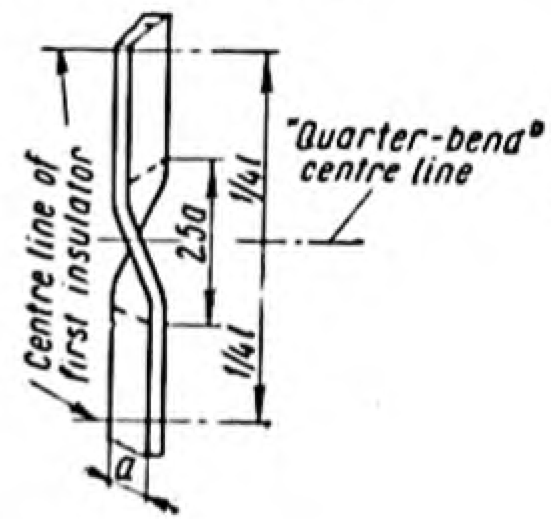
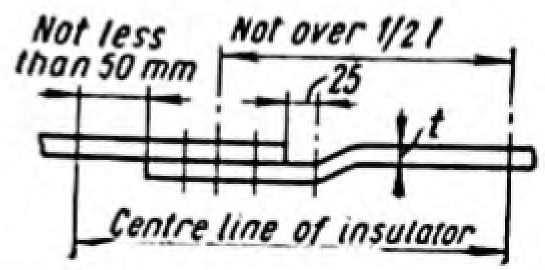
Sequence of Basic Operations for Busbar Installation

Operation	Requisite tools, fixtures and mechanisms *	Procedure
Selection	Folding rule, tape-measure, vernier caliper	Pick out busbars by cross section and length. Attach tags or mark the selected bundles to indicate where they are to be used. Draw up a list of the busbars that are available, selected, and to be procured.
Straightening of busbars	Straightening rolls, straightening plate, screw press, winch, wooden mallet, 800-gram hammer, aluminium and wood pads	Straighten busbars whenever their curvature is greater than 2 mm per running metre. Busbars must be cold when being straightened. In the case of large-scale work, straightening rolls or screw presses should be used. On small sites a straightening plate, a wooden mallet or hammer and pads of a softer material may be used. For copper busbars the pads may be of aluminium; for aluminium busbars, of the same material or of wood. Busbars of small cross section received in coils are uncoiled and straightened by means of a winch.
Making templates for bar bending and marking out	Vise, 500- or 600-gram hammer	Templates are made to the working drawings from hot-rolled steel wire 4 to 6 mm in dia. Templates are bent to shape so that they coincide with the axis of the busbar. The length of each template is then measured and the busbars are cut to these measured lengths.

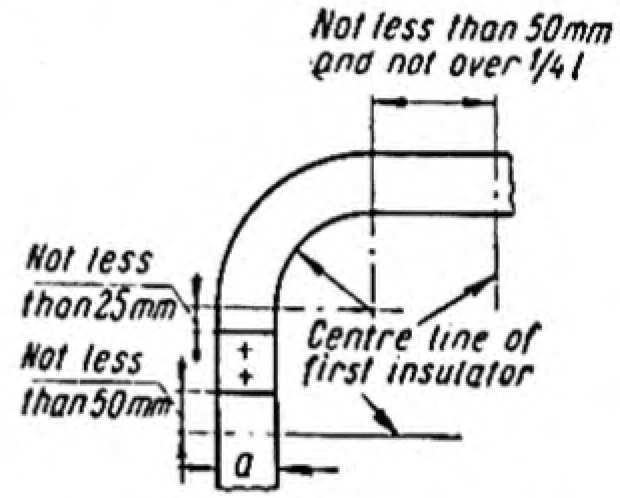
* Some of the tools, fixtures and mechanisms used in busbar installation are shown in Figs 135 to 139.

Operation	Requisite tools, fixtures and mechanisms	Procedure
Cutting of busbars	Hack saw, circular saw, bastard files, УПП and ПН-1 presses	Hack-sawing, as a very unproductive operation, is used only when the scale of work is limited. A more attractive method is to cut busbars on УПП and ПН-1 shearing presses, and a friction saw. A disadvantage of the latter is the burrs that remain at the cut ends and have to be removed with files.
Bending of busbars	Busbar bender, offset bending die, quarter-turn bending fixture, portable forge	Busbars are bent to templates placed on centre line of busbar. Busbars can be: (a) bent on flat  Dimension l is the distance between supports of busbar

Continued

Operation	Requisite tools, fixtures and mechanisms	Procedure
		(b) quarter-turn bent  (c) offset bent 

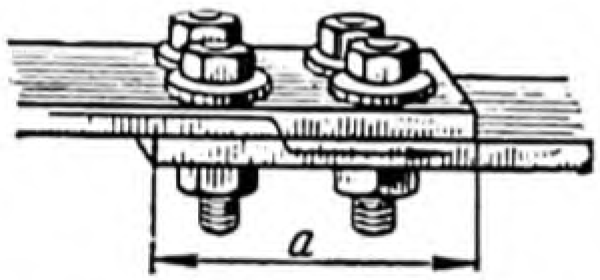
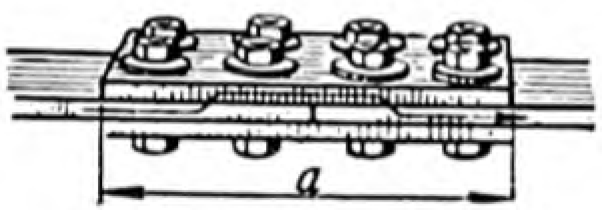
Operation	Requisite tools, fixtures and mechanisms	Procedure
		(d) bent on edge

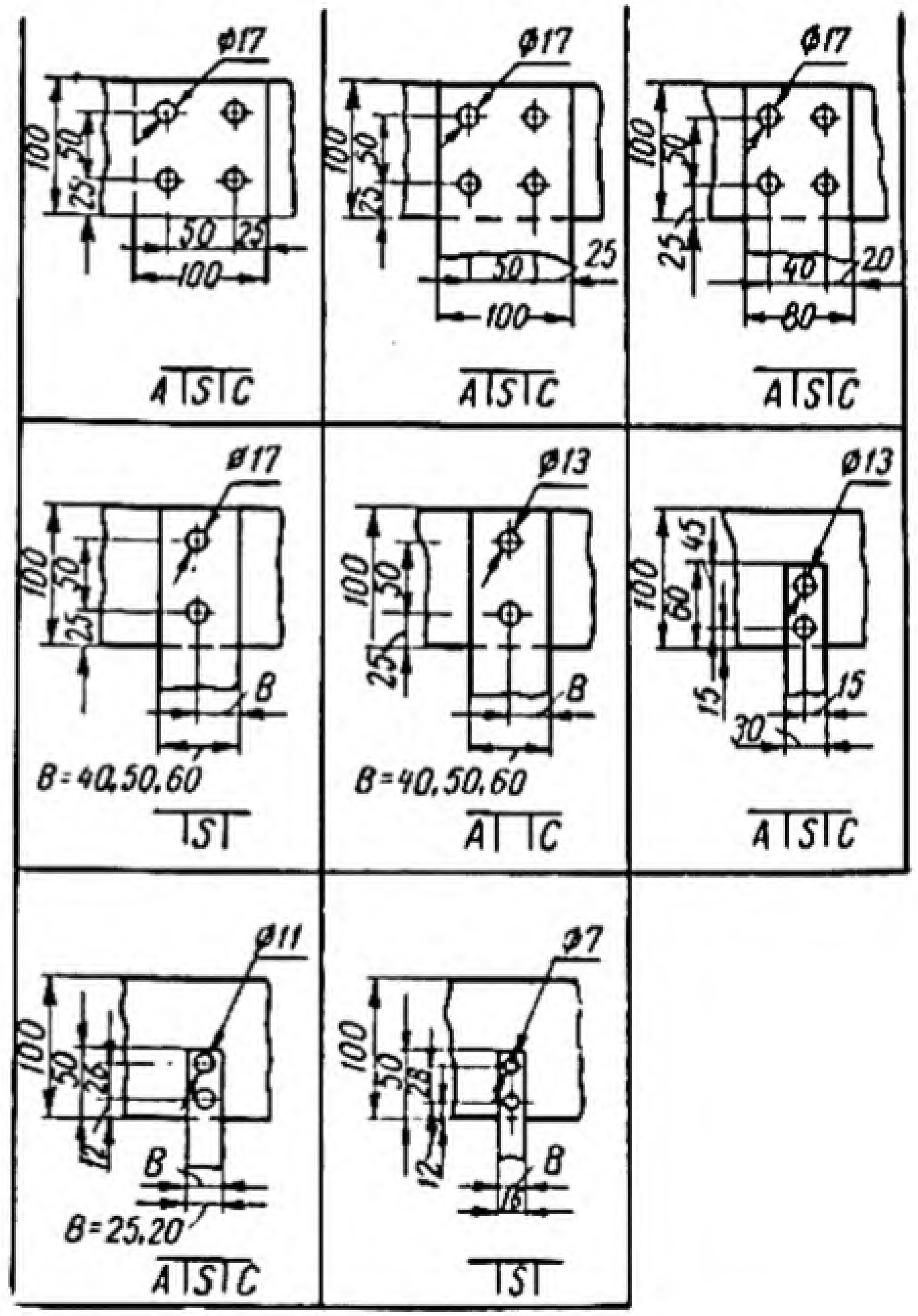


Minimum bending radius may be taken from the following table:

Type of bend	Busbar size, mm	Minimum radius of bend from inner edge		
		Copper	Alu-minium	Steel
Bend on flat	Up to 50×5	2 t	2 t	2 t
	Up to 100×10	2 t	2.5 t	2 t
Bend on edge	Up to 50×5	a	1.5 a	0.5 a
	Up to 100×10	1.5 a	2 a	a

Note: a—busbar width, t—busbar thickness

Operation	Requisite tools, fixtures and mechanisms	Procedure
Joining of busbars with bolts: (a) lap joint  		Used for main busbars up to $100\times\times10$ mm in cross section, and also for tap-off busbars run to apparatus. Overlap should be at least two bus widths. Bar ends should be offset at the joint to keep bars and insulators on a common centre line.
(b) strap butt joint  		Should be used for main busbars only. In multibar buses separators should be placed between the bars. There should always be two straps and one separator fewer than there are bars. Both straps and separators should be two bar widths in length.
Preparation of bars for bolted joints: (a) marking out of holes on main busbars	Rule, back square, scriber, centre punch	Prior to marking out, make sure that the joint or tap-off will not be over a support insulator.

Operation	Requisite tools, fixtures and mechanisms	Procedure
		Typical examples of bolt-hole layouts*. 

* The letters *A*, *S* and *C* stand for aluminium, steel and copper, respectively.

Continued

<table>
<tr><th>Operation</th><th>Requisite tools, fixtures and mechanisms</th><th>Procedure</th></tr>
<tr><td>(b) drilling or punching of holes in bars</td><td>УПП, ПН-1 presses, drilling machines, electric drills</td><td>Electric drills are used where small-scale work has to be done or a bent bar is difficult to drill on a machine.
The sizes of bolts and holes may be taken from the following table:
<table>
<tr><th colspan="2">Diameter, mm</th><th colspan="2">Diameter, mm</th></tr>
<tr><th>bolt</th><th>hole</th><th>bolt</th><th>hole</th></tr>
<tr><td>6</td><td>7</td><td>12</td><td>15</td></tr>
<tr><td>8</td><td>9</td><td>14</td><td>16</td></tr>
<tr><td>9</td><td>10.5</td><td>15</td><td>17</td></tr>
<tr><td>10</td><td>11.5</td><td>16</td><td>18</td></tr>
<tr><td>12</td><td>13.5</td><td>18</td><td>20</td></tr>
</table>
</td></tr>
<tr><td>(c) working of contact surfaces</td><td>Vise, bastard files, bar milling machines, wire-brush machine</td><td>Files are only used for small-scale work. When bar surfaces are free from serious defects contact surfaces may be cleaned on a wire-brush machine.
Surface working for aluminium bars consists of:
(1) rough finishing on a bar-milling or a wire-brush machine;
(2) cleaning with a steel-wire brush under a coating of petroleum jelly;
(3) removal of filings and petroleum jelly, and application of fresh petroleum jelly to contact surfaces;</td></tr>
</table>

Operation	Requisite tools, fixtures and mechanisms	Procedure
		(4) final cleaning immediately before joining with a steel-wire brush under a coating of petroleum jelly to be left on contact surfaces. The point to be kept in mind in all cases is that bar thickness at a joint may be reduced by not more than 1 to 2 per cent.
(d) Tinning of contact surfaces on copper and steel bars	Solder melting ladle, wiping cloth	Copper bars should be tinned at the joints only when located outdoors or in locations laden with moisture or aggressive gases or when the ambient temperature exceeds 60°C. Steel bars must always be tinned at the joints. Tinning should be done with ПОС-30 (30 per cent) tin-lead solder (or 90% tin-lead solder in critical cases), with rosin or a soldering paste as flux. Contact surfaces of copper and steel bars thus worked should be coated with petroleum jelly and wrapped in paper to protect them from mechanical injury. Prior to bolting up a joint, the petroleum jelly should be washed off with petrol and a thin coat of fresh petroleum jelly should be applied.

Continued

Operation	Requisite tools, fixtures and mechanisms	Procedure
Bolting of joints	Adjustable-lever turned open-end and box spanners	When bolting up a contact joint steel spring washers should be placed under nuts to permit bars to expand freely at the joint due to temperature rise, to lock nuts, and to protect bar material under nuts and bolt heads from denting. Bolts should be tightened with a spanner by hand.

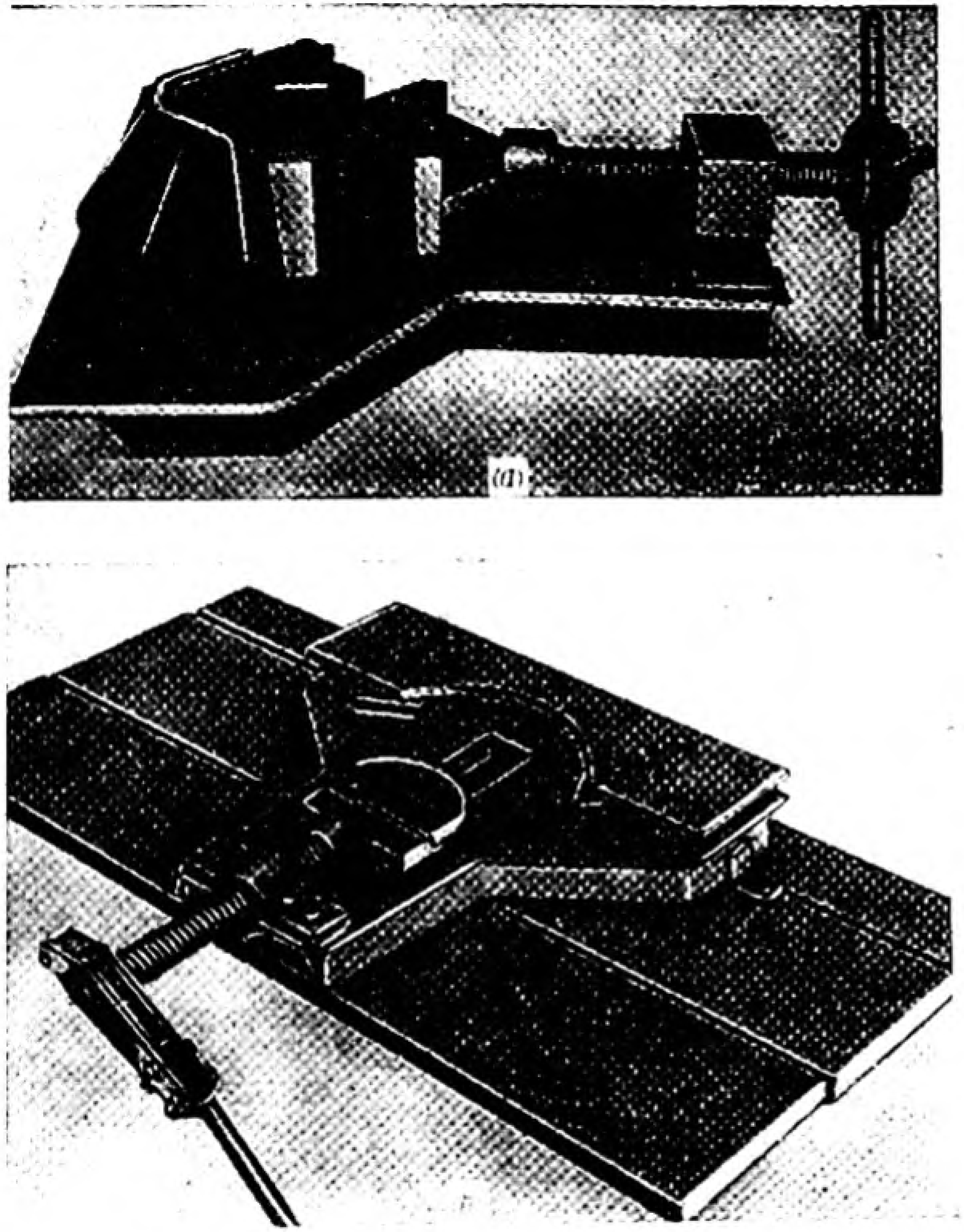


Fig. 135. Screw-type busbar benders:
a—on-flat bender; *b*—on-edge bender

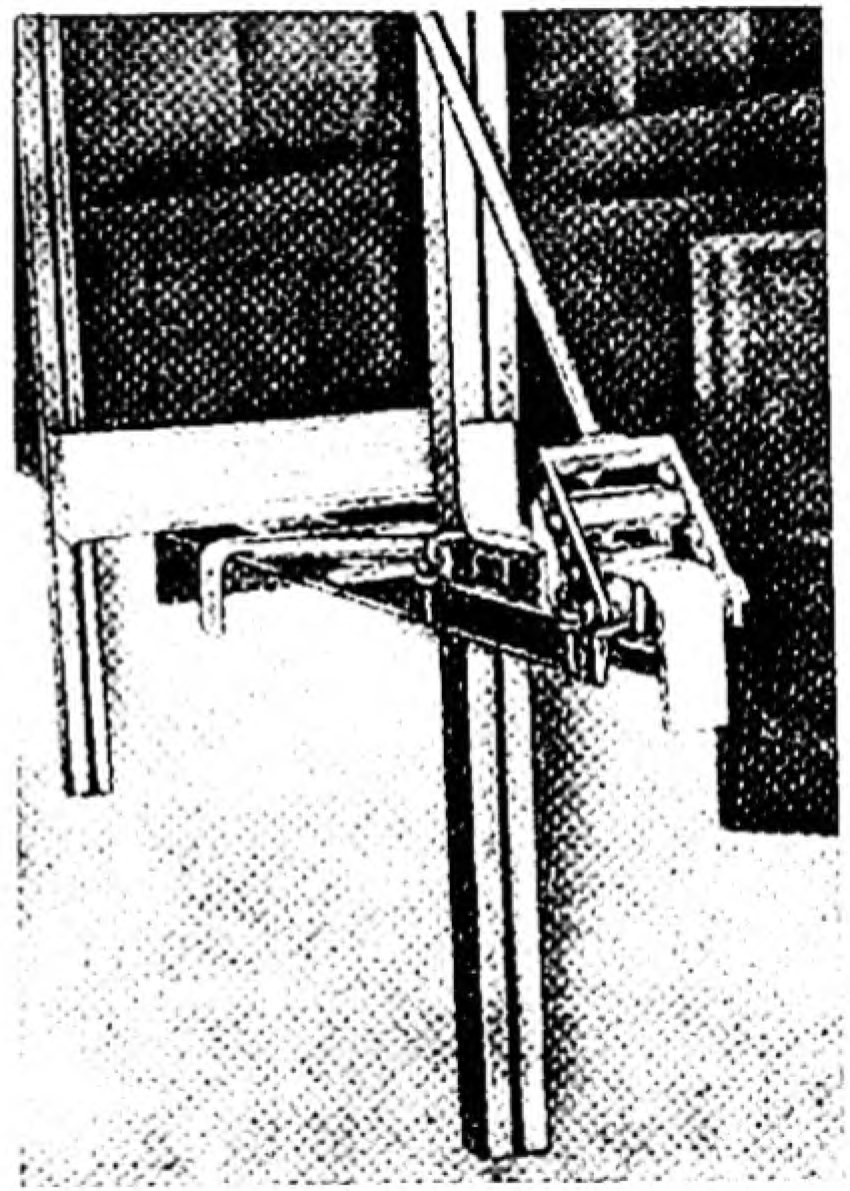


Fig. 136. Roller-type on-flat busbar bender

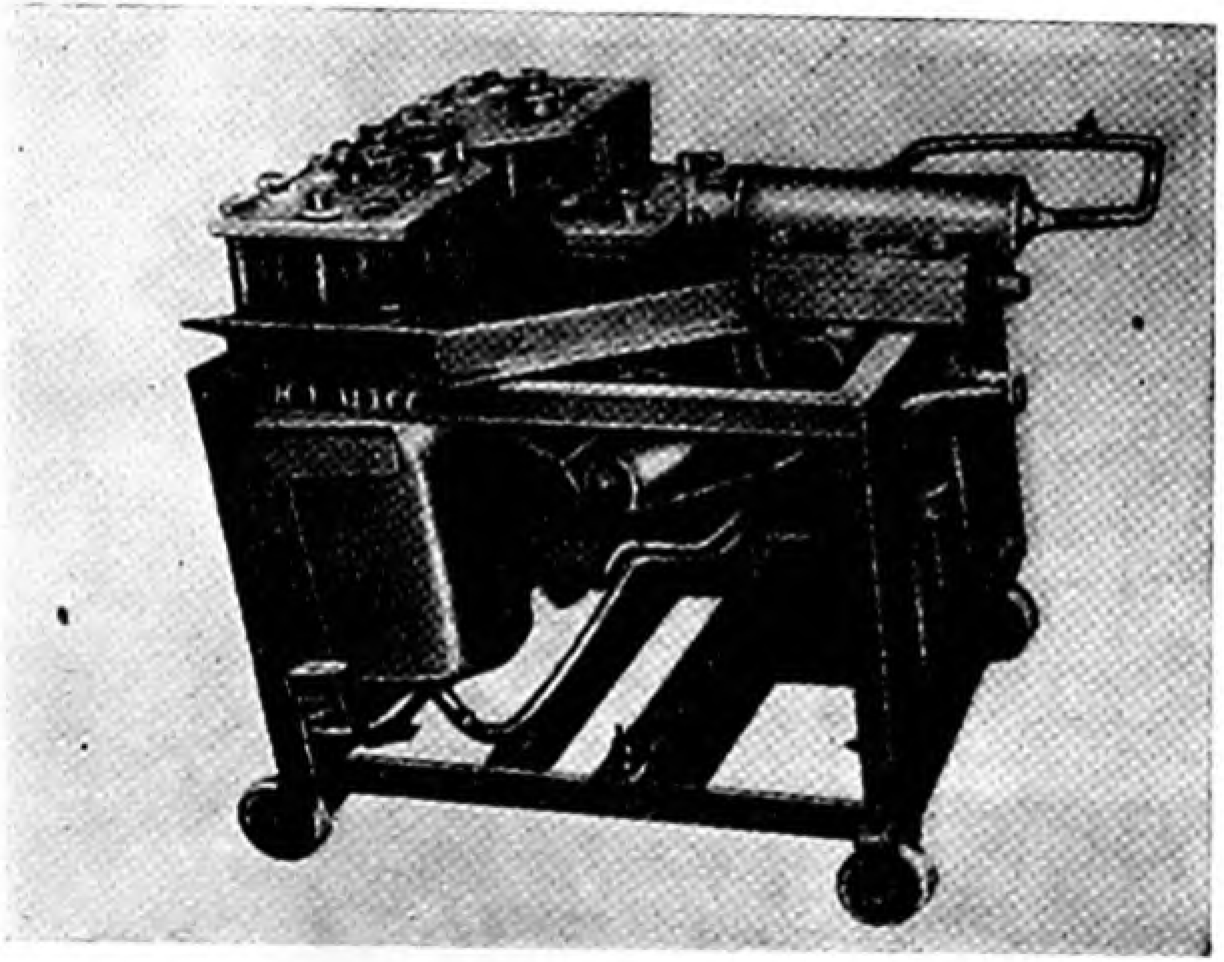


Fig. 137. Hydraulic busbar bender

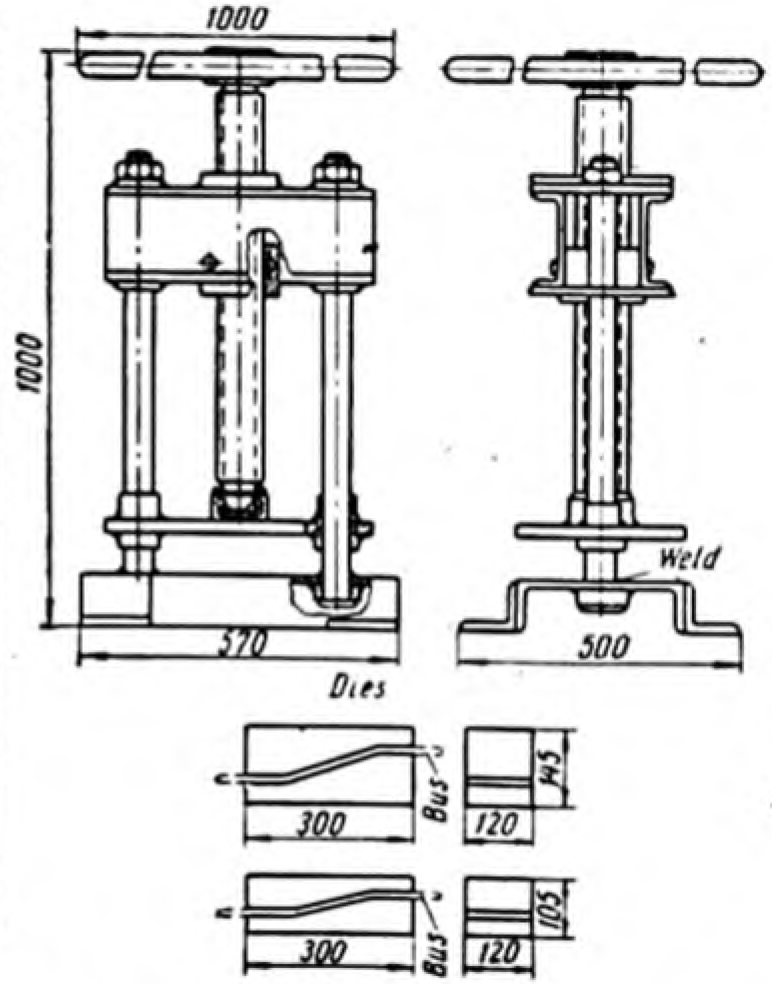


Fig. 138. Offset bending screw press

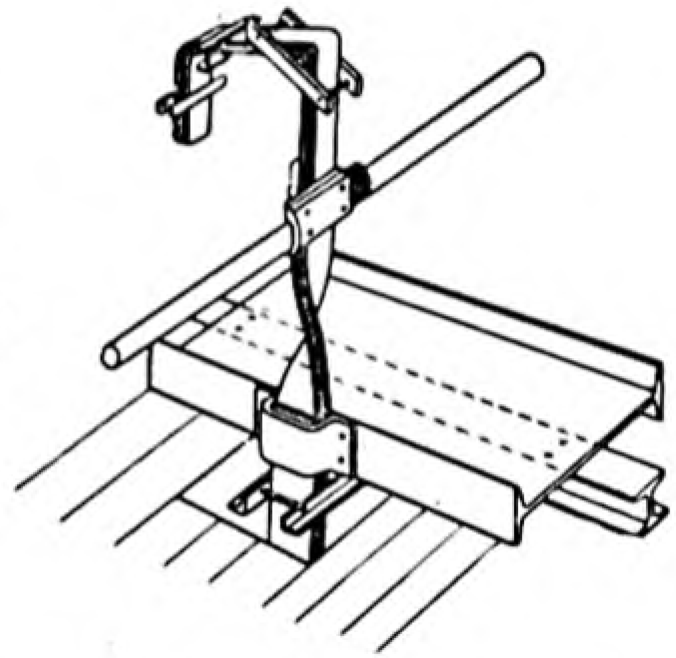


Fig. 139. Quarter-turn bending fixture

Jointing of bars by electrical welding and diffusion bonding. Of late an a-c welding process has been used for bar joining (Fig. 140 *a*) in the Soviet Union. This work is done by qualified welders.

Another method is diffusion bonding. It is based upon the bonding of metals under high pressures, whereby strong joints are made. Diffusion bonding is used to make lap joints (Fig. 140*b*). The overlap should be at least equal to busbar width, or greater if the number of indentations to be made is large. The number of indentations is determined by calculation and is specified together with the overall dimensions of the joints.

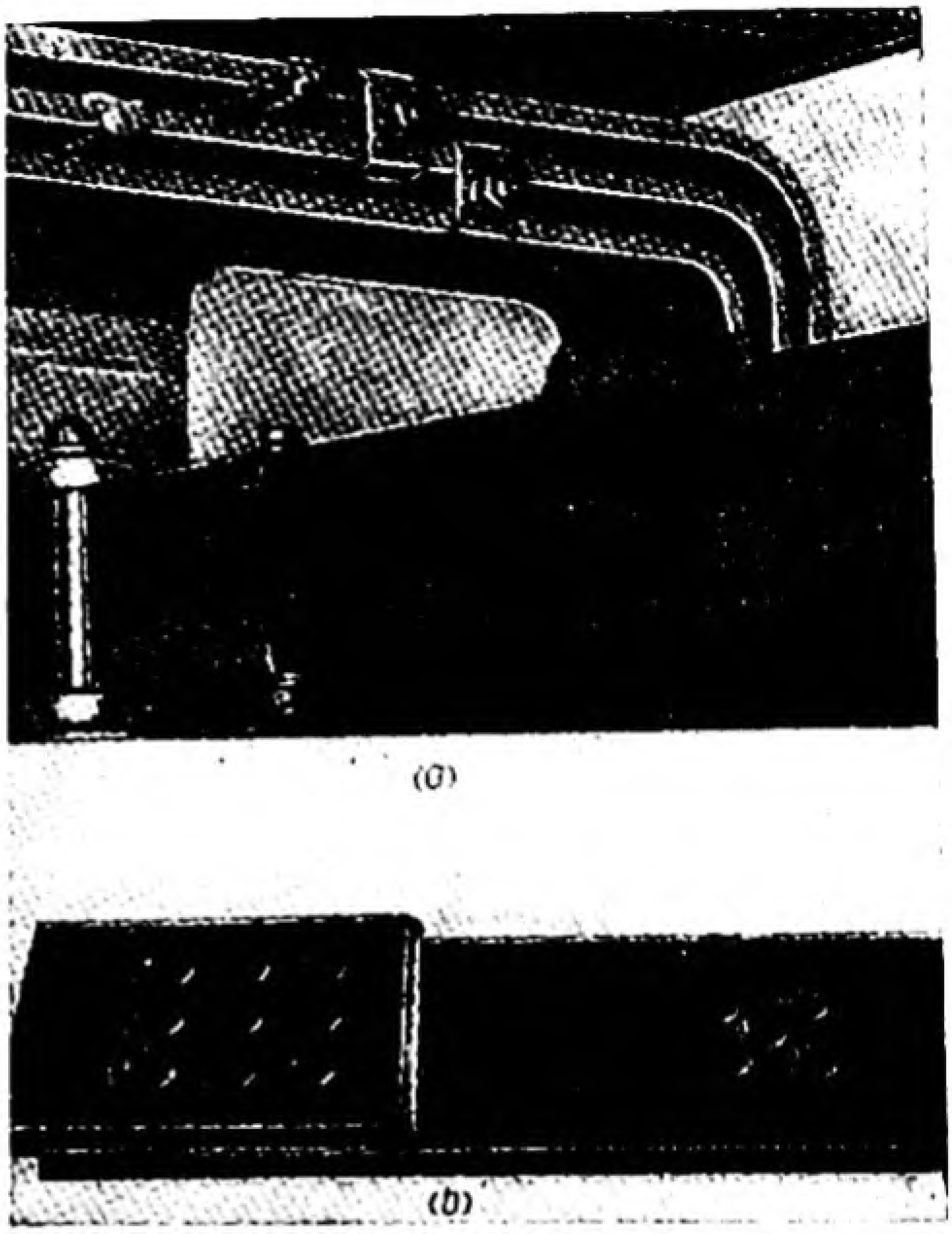


Fig. 140. Busbar jointing:
a—by a-c welding; *b*—by pressure welding (indentation for diffusion bonding)

Before making a joint, the surfaces of the bars must be thoroughly cleaned with a steel-wire brush and then given a thin coating of pure petroleum jelly to prevent oxidation. The buses are then placed between the dies of a НГП hydraulic press (see Fig. 4) where the bar metal is diffusion-bonded from both sides.

The jigs and dies to be used are chosen in sizes to suit the specified requirements.

The end of a bonding cycle is indicated by the considerable increase in the force that must be applied to the hydraulic-press operating lever. The check on the thickness of the metal under the dies is provided by an indentation depth indicator. Reference data for diffusion bonding are given in Table 19.

Table 19

Aggregate Thickness of Bar Metal Under Dies at End of Indentation Period

Main bar size	Metal thickness for tap-off bar width, mm				
	100	80	60	50	40
100×10	2	1.8	1.7	1.5	1.5
80×8	—	1.6	1.5	1.3	1.3
60×6	—	—	1.4	1.2	1.2
50×5	—	—	—	1.0	1.0
40×4	—	—	—	—	1.0

Note: The above data are valid for aluminium bars.

Installation of buses. From the general view of a main busbar section in the substation shown in Fig. 141 it can be seen that the buses may be installed on flat and on edge and held in place by clamps. In some cases branch or tee-off buses may be secured directly to the caps of the support insulators (Fig. 142*a*).

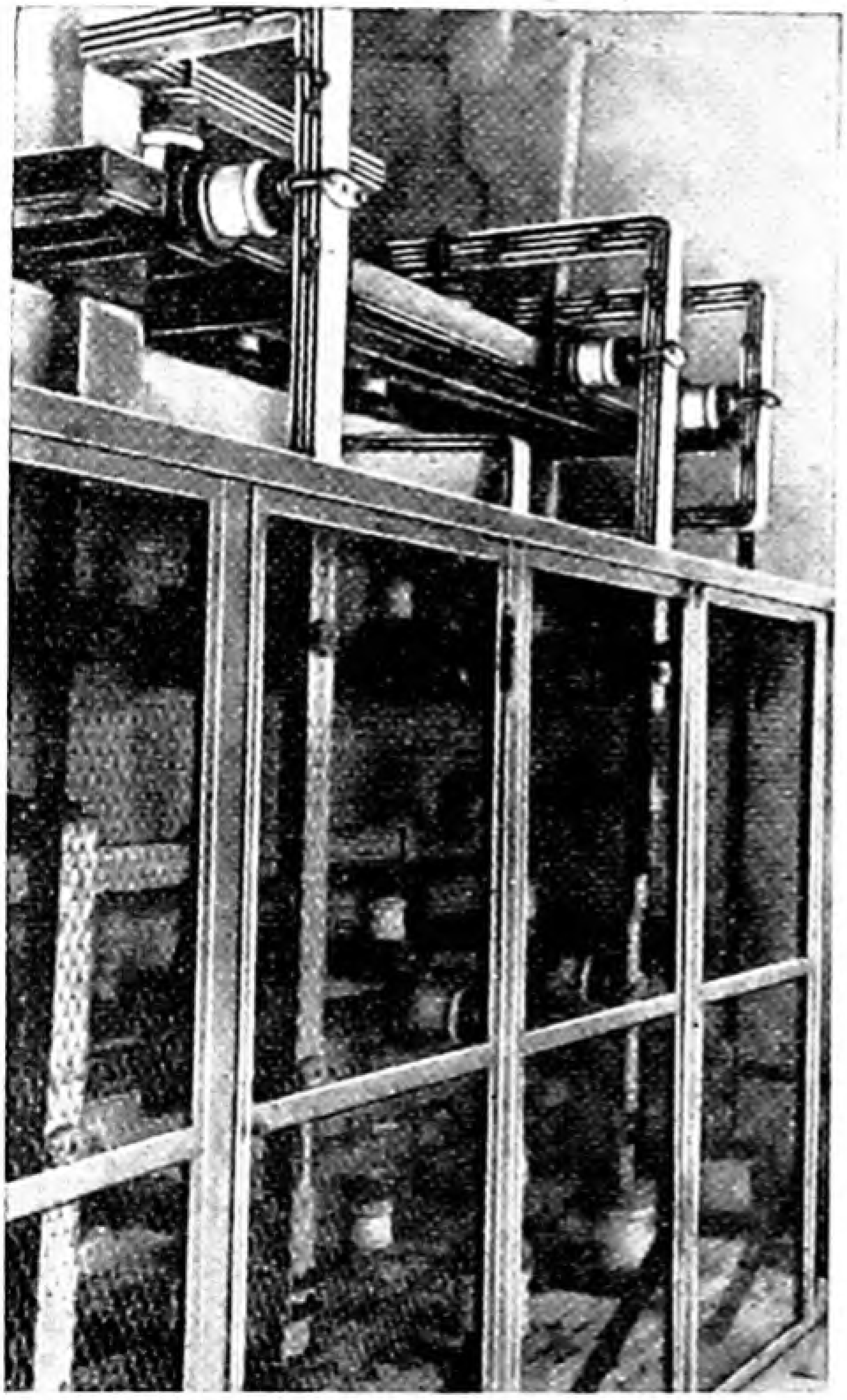


Fig. 141. General view of main busbar section in an indoor substation

In any case, however, buses must be free to expand due to the heat generated by their load and short-circuit currents. Otherwise, the internal stresses set up in them may grow to a point where they will cause warpage to the busbars or, if a heavy short-circuit current flows, even destroy the entire busbar structure.

Because of this, busbar clamps have a clearance of 1.5 to 2 mm (Fig. 142 *b*, *c*) so that the busbars cannot be clamped dead-fast. For the same reason single-bar buses installed on the insulator caps have oval mounting holes and the bolts have spring washers placed under their heads (Fig. 142*a*).

Bus structures more than 15 metres long must be provided with expansion compensators (Fig. 143 *a* and *b*) permanently fastened at some points as shown in Fig. 144.

In indoor substations buses are installed in the following sequence:

First busbar clamps are attached to the caps of the support insulators and the busbars are placed on them. Then the busbars are trued with respect to the longitudinal axis with a wire and levelled with a batten and spirit level. After this, the tee-off busbars, shaped

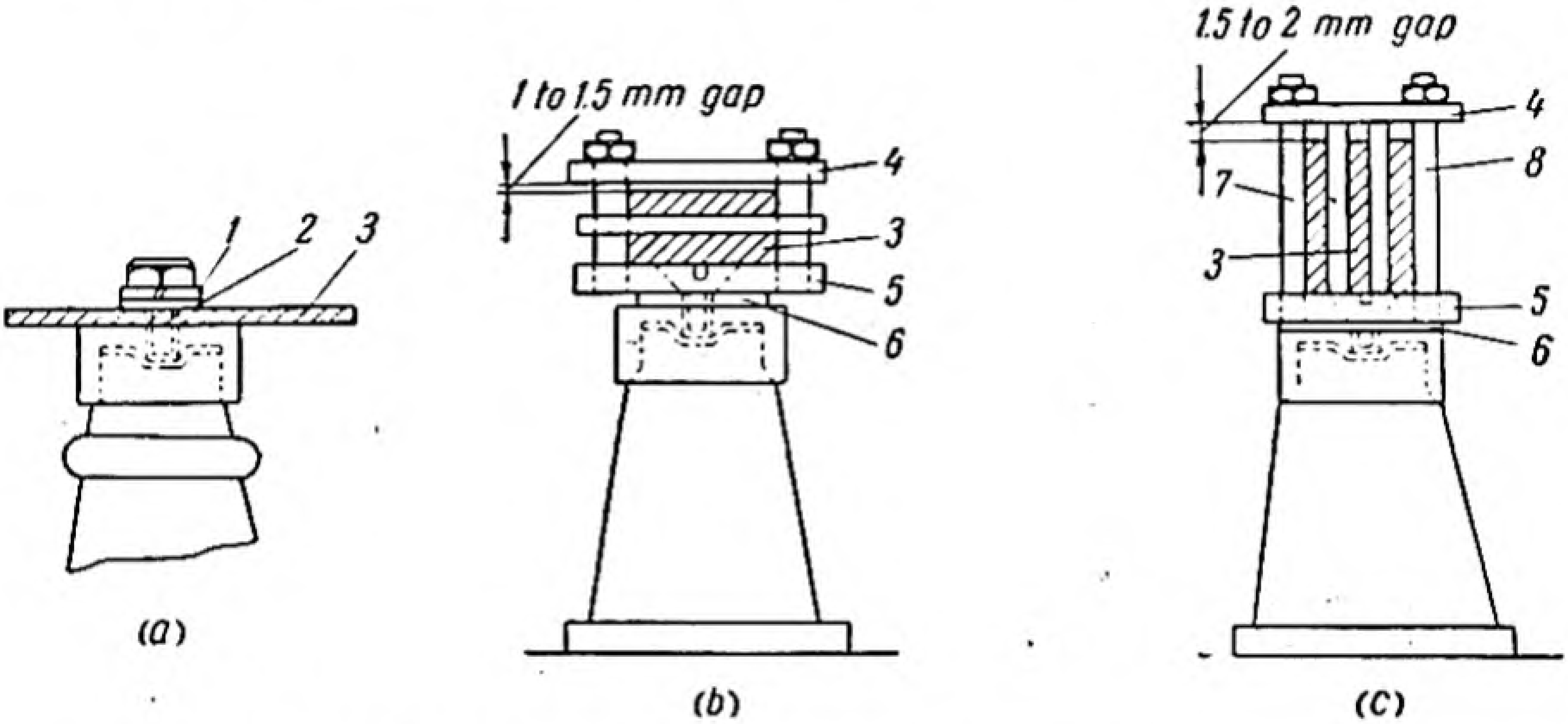


Fig. 142. Methods of securing busbars on support insulators:
a—directly on insulator cap; *b*—on-flat in busbar clamp; *c*—on-edge in busbar clamp: *1*—spring washer; *2*—steel washer; *3*—busbar; *4*—upper plate; *5*—lower plate; *6*—cardboard pad; *7*—steel stud; *8*—brass stud

to templates, are trimmed and placed. Finally, the busbars are joined up and expansion compensators are installed.

Following the above operations, the buses are connected to the associated switchgear.

Mounting of busbar clamps. One of the studs locking a clamp is made of a nonmagnetic material (brass) to reduce heating and the accompanying loss of power, as the magnetic circuit is disrupted and no eddy currents can be induced in the clamp parts.

Buses installed in a common horizontal plane are frequently mounted in their clamps on edge. In such cases, the clamps should be turned so that the dynamic forces developed by the flow of short-circuit currents will tend to tighten rather than loosen their bolts.

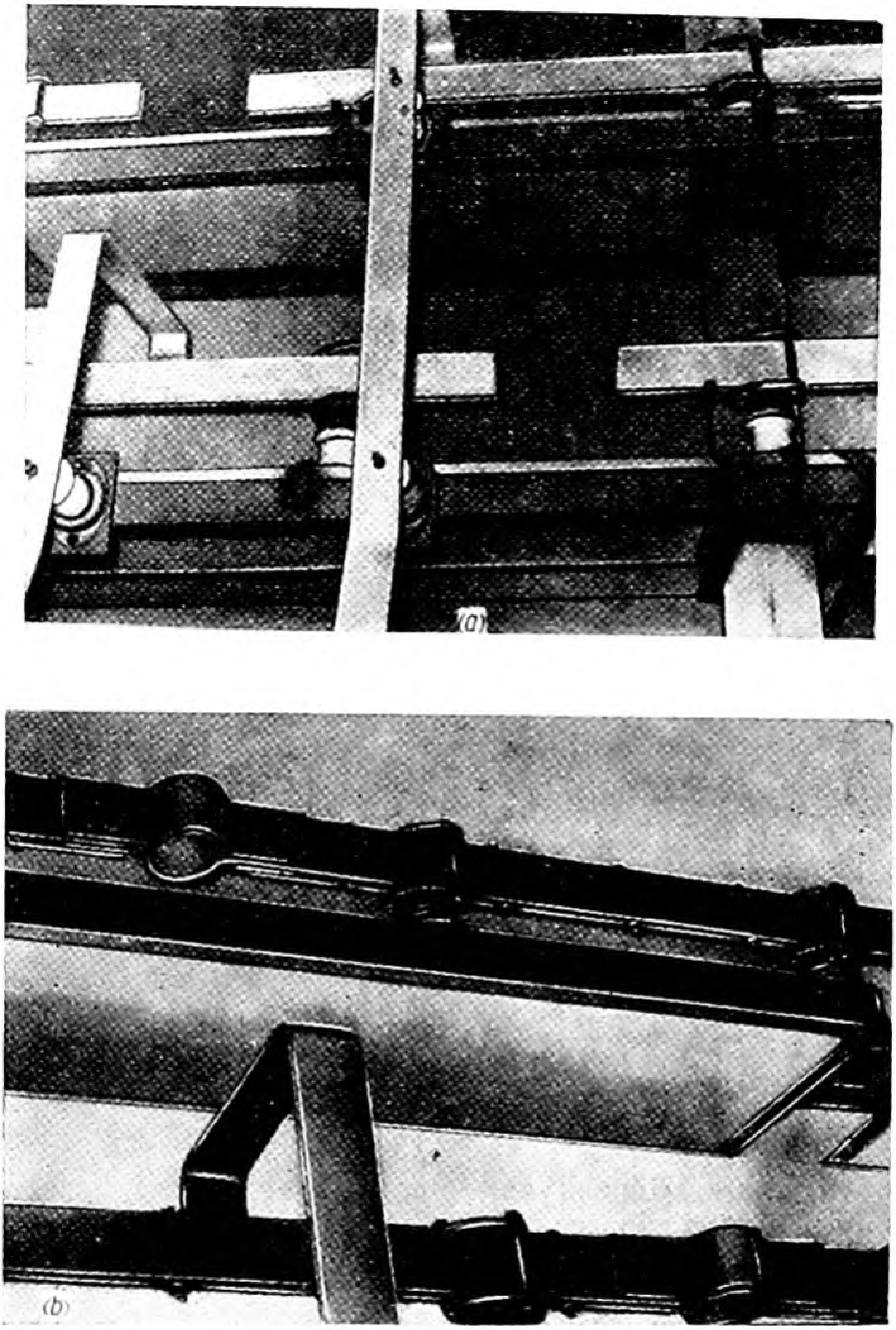


Fig. 143. Bus expansion compensator mounting:
a—buses ready for jointing compensator; *b*—compensators joined by welding

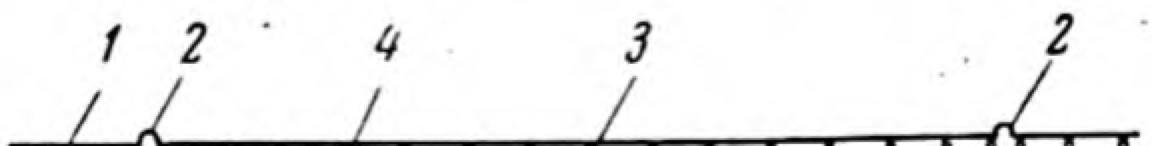
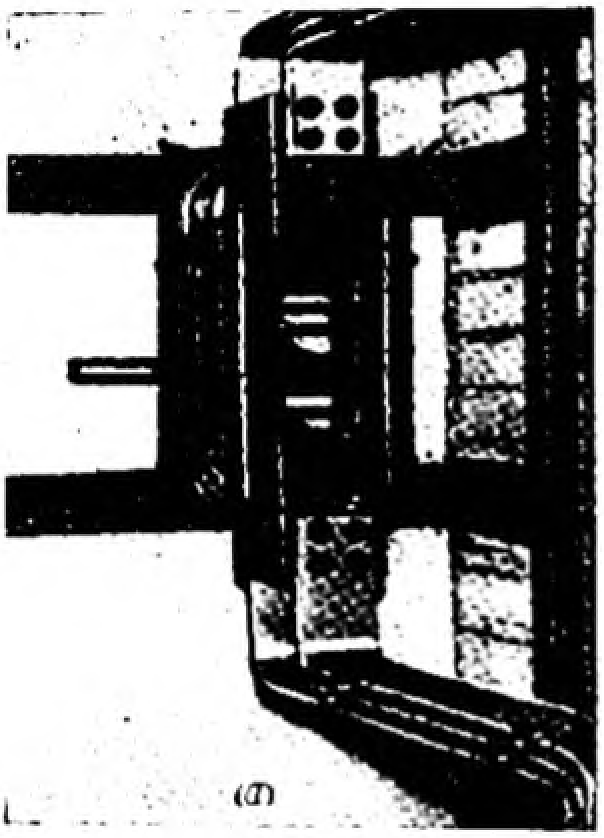


Fig. 144. Arrangement of expansion compensators and points of rigid fastening:
1—busbar; *2*—compensator; *3*—point of rigid fastening; *4*—support insulator

Connection of busbars to switchgear contacts. This operation poses difficulties in that it may be performed in many ways and that aluminium busbars have to be joined to copper switchgear parts.

Wherever possible, buses should be connected directly to the associated equipment. Four contact bolts on a terminal will suffice to obtain a reliable electrical contact (Fig. 145*a*).

With fewer bolts as, for example, on PB-10/600 isolators which have but one bolt per phase, it is good practice to pressure-weld a copper strap onto the aluminium busbar at the joint (Fig. 145*b*).



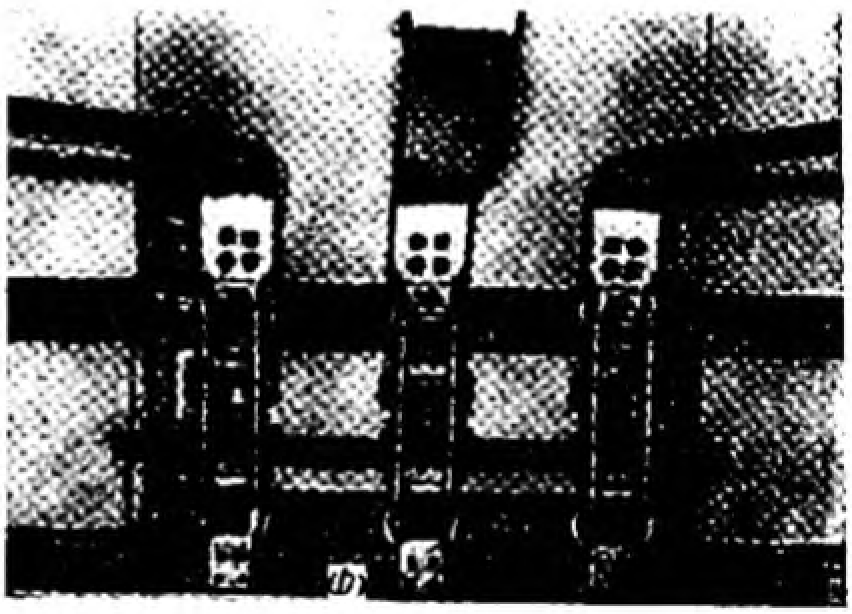


Fig. 145. Bus connections to isolator contacts:
a—direct connection to PBK isolator bar terminal; *b*—connection made to PB isolator through a copper strap pressure welded to aluminium busbar

As operating experience has shown, fair results may be obtained by using composite butt-welded copper-aluminium straps. The aluminium end of the strap is welded to a busbar and the copper end is connected to the apparatus.

Sometimes buses are welded directly to the contacts of the apparatus.

It is obvious that the smaller the number of joints, the higher the quality of the installation and switchgear reliability. For this reason several Soviet electrical construction organisations prefer to remove the bars out of bushings and pass the tee-off bars directly through them (Fig. 146).

Figs 147 through 152 show typical sections and assemblies of bus structures in indoor substations.

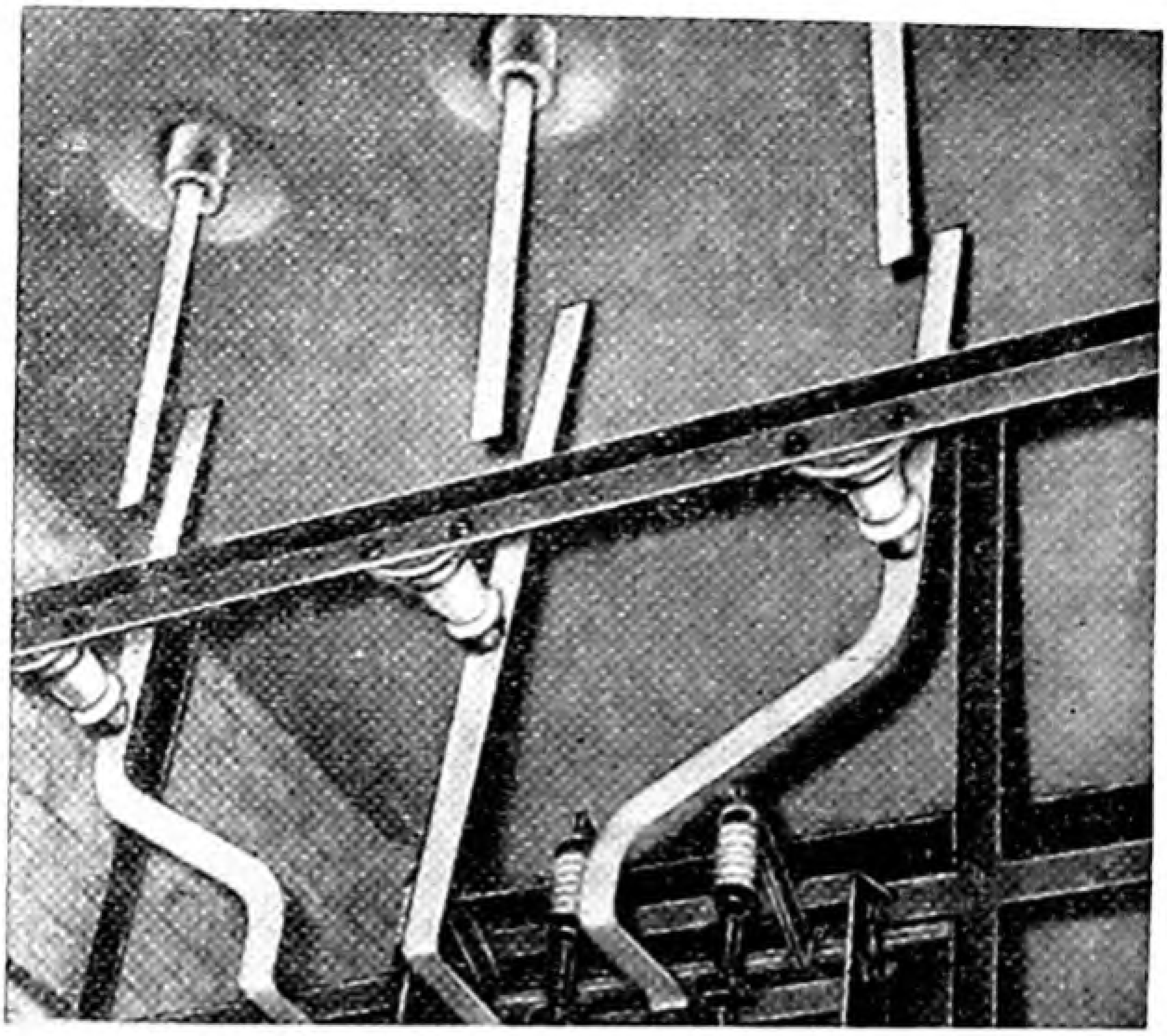


Fig. 146. Busbars passed through ПА-6/600 bushings from which conductor bar has been removed for direct connection to circuit breaker

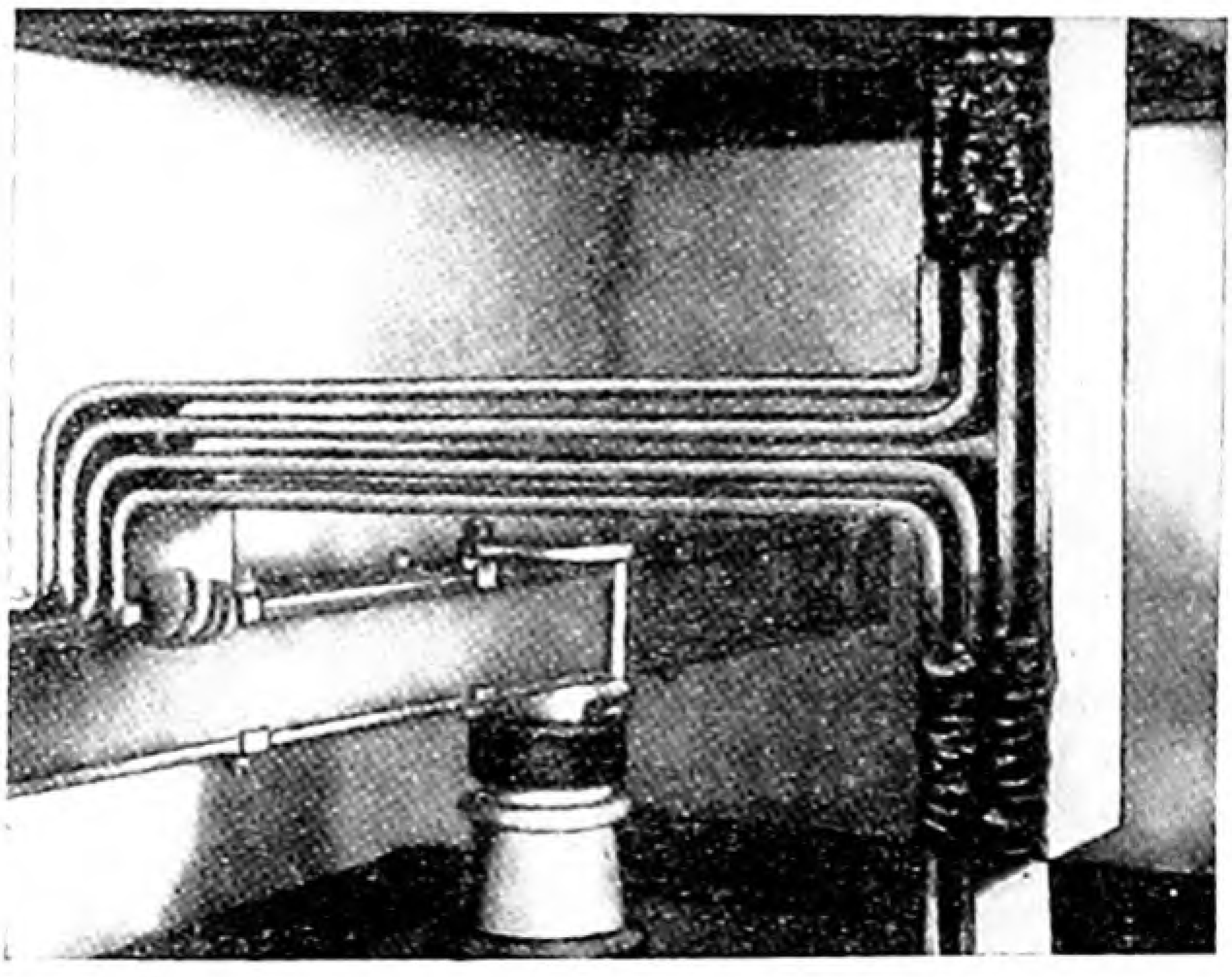


Fig. 147. Intricate bus assembly with welded joints

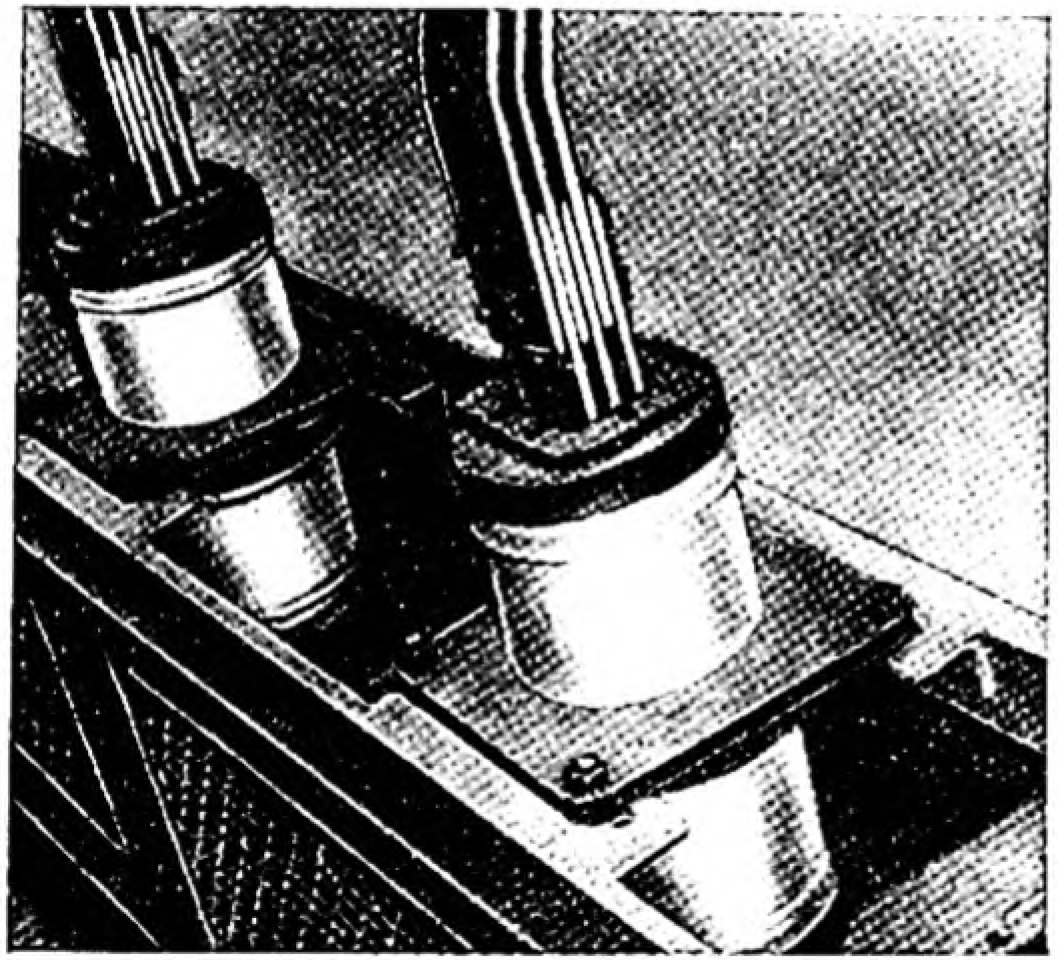


Fig. 148. Multibar buses passed through ИПШ-II-10 bushings

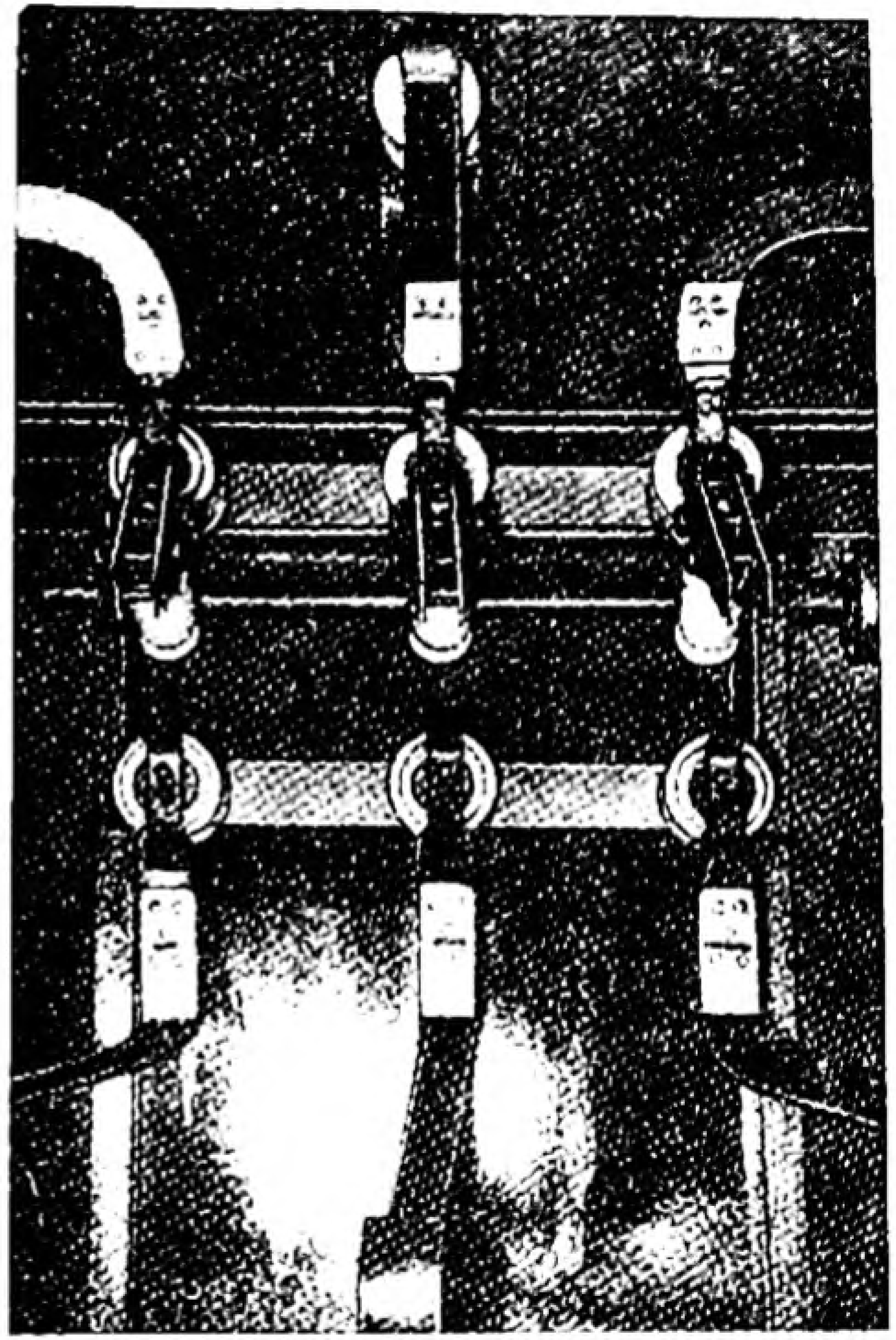


Fig. 149. Buses connected to an isolator with the bars bent on a radius

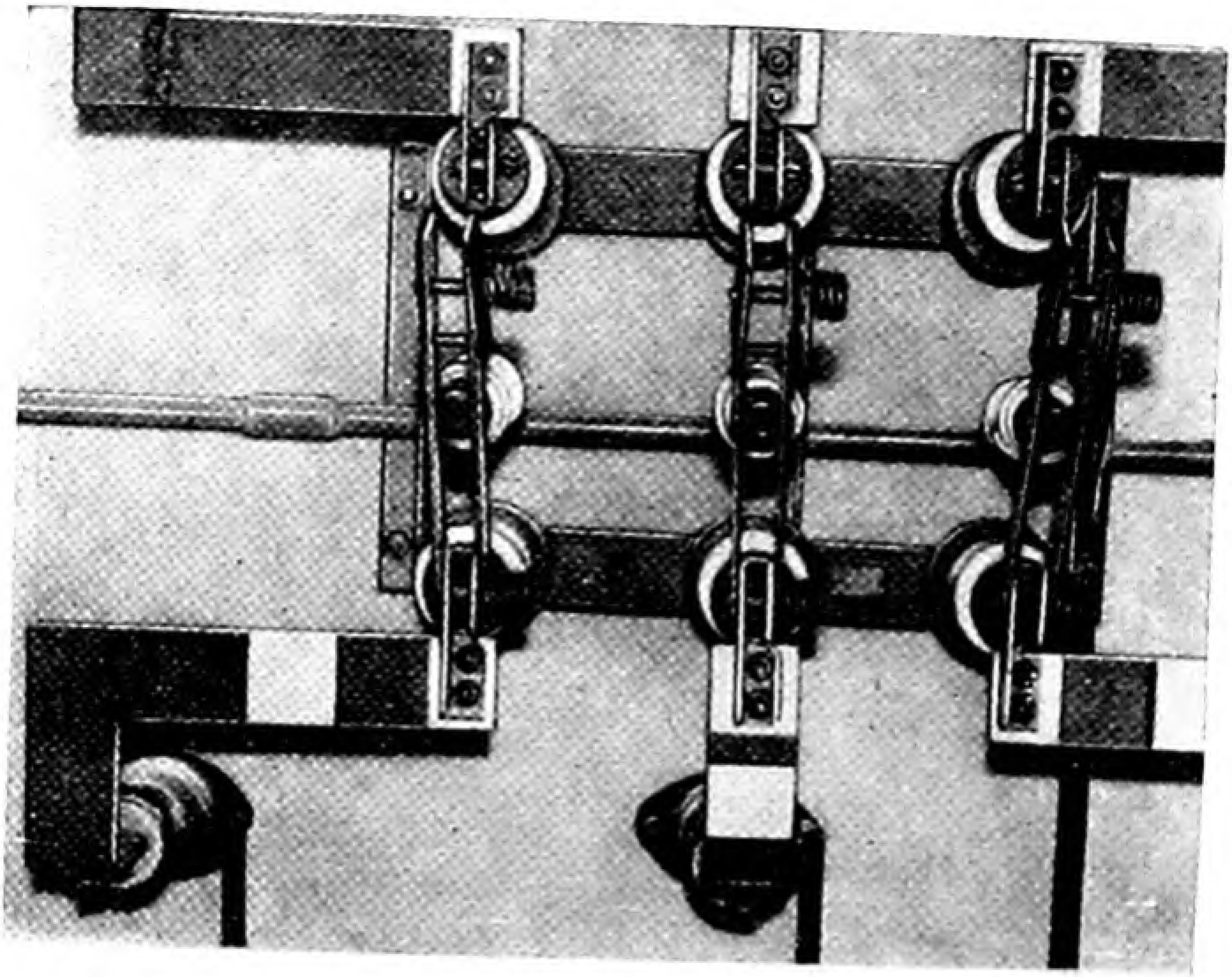


Fig. 150. Buses connected to isolator with welded joints to avoid bends

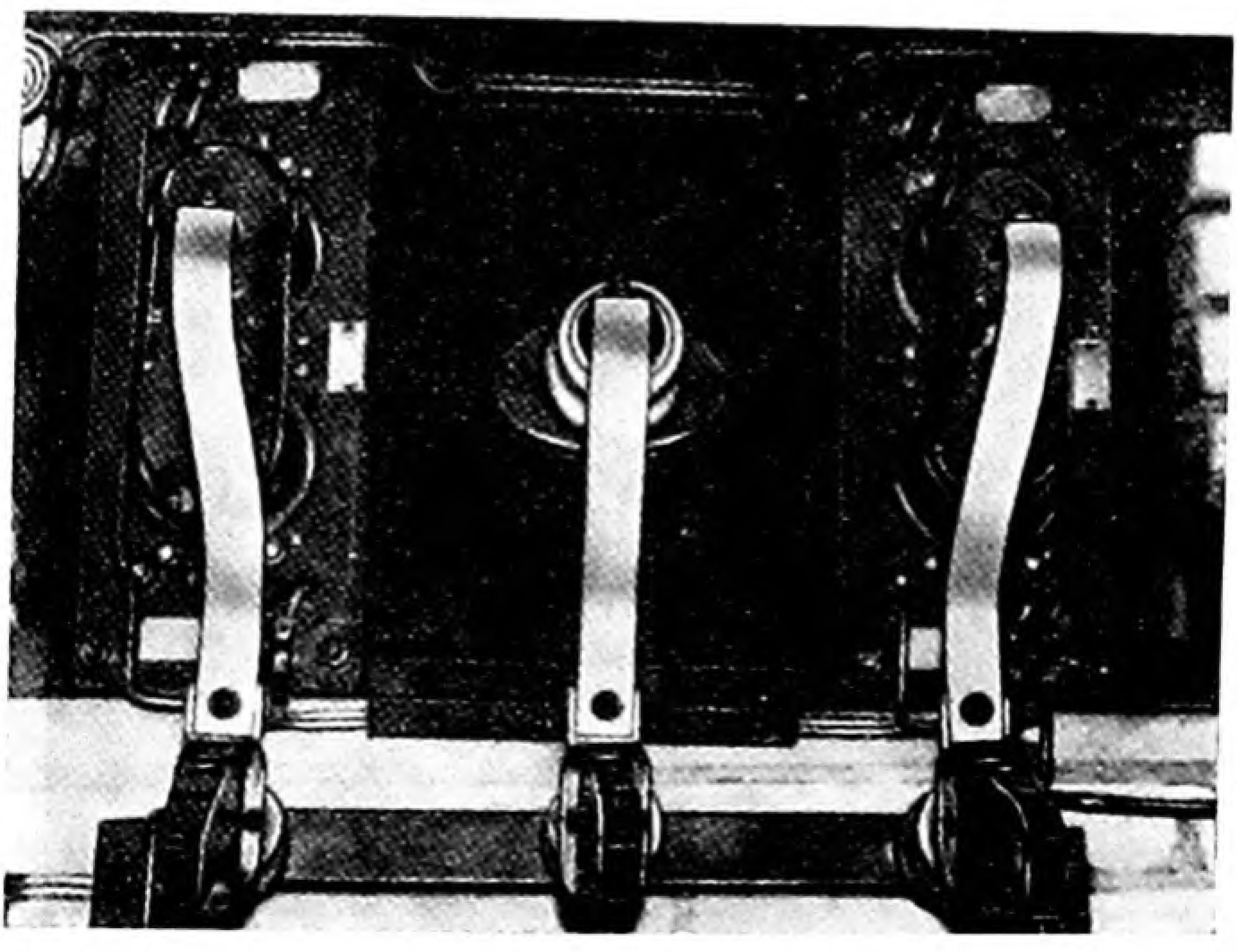


Fig. 151. Example of bus connections of two ТПФ current transformers and a ПА bushing

Painting of buses. Painting is the last operation in busbar installation. Busbars are painted in different colours for phase identification (colour coding), anticorrosion protection, and better heat radiation.

Fig. 152. View of buses at a cable terminating point

Special enamels are used for the purpose. Single-bar buses are painted on all sides. Multibar buses are only painted on the outside and edges.

Bolted joints and places on the buses where temporary safety earthing sets are attached are left unpainted. The latter are contoured with a black paint.

Bus clamps are painted together with their buses.

The standard colour code for buses is as follows:

Yellow for 1st phase (A)

Green for 2nd phase (B)

Red for 3rd phase (C)

Black with white stripes for unearthed neutral

Black with violet stripes for earthed neutral

Claret or red for positive d-c pole

Blue for negative d-c pole.

Irrespective of location, the middle phase (B) should be painted green. Of the outer phases the left-hand may be painted red and the right-hand yellow, or vice versa, provided the bus colour code is consistent with that adopted for the whole system.

The arrangement of the phases in a substation in a definite sequence is called phasing in. It should conform with that of the transformers, generators, and incoming lines.

Provision of temperature indicators on bus joints. In indoor substations a check on the temperature of bolted bus joints is provided by pasted-on temperature-sensitive films. These films change colour as the joint temperature rises. As an alternative, circular pieces of film can be pasted on the bolt heads.

The surfaces to be covered with a temperature-sensitive film should be thoroughly cleaned and wiped with a cloth moistened with petrol, and then given a coat of benzyl-cellulose varnish, the film is then applied and finished with the same varnish.

Problem. 1. Write up an operation sequence for bolting aluminium busbars 100×10 mm in size.

2. Write up an operation sequence for bus installation.

23. Installation of KPУ and KCO Factory-assembled and Prefabricated Switchgear

Installation of KPУ (truck-type) metal-clad switchgear. The advantages of metal-clad, factory-assembled switchgear are extensive factory construction, reduced installation time, and improved quality of installation work.

The only thing left for the electricians to do is to set up KPУ units on the site and connect them into the specified circuits.

A KPУ unit can be seen in Fig. 153.

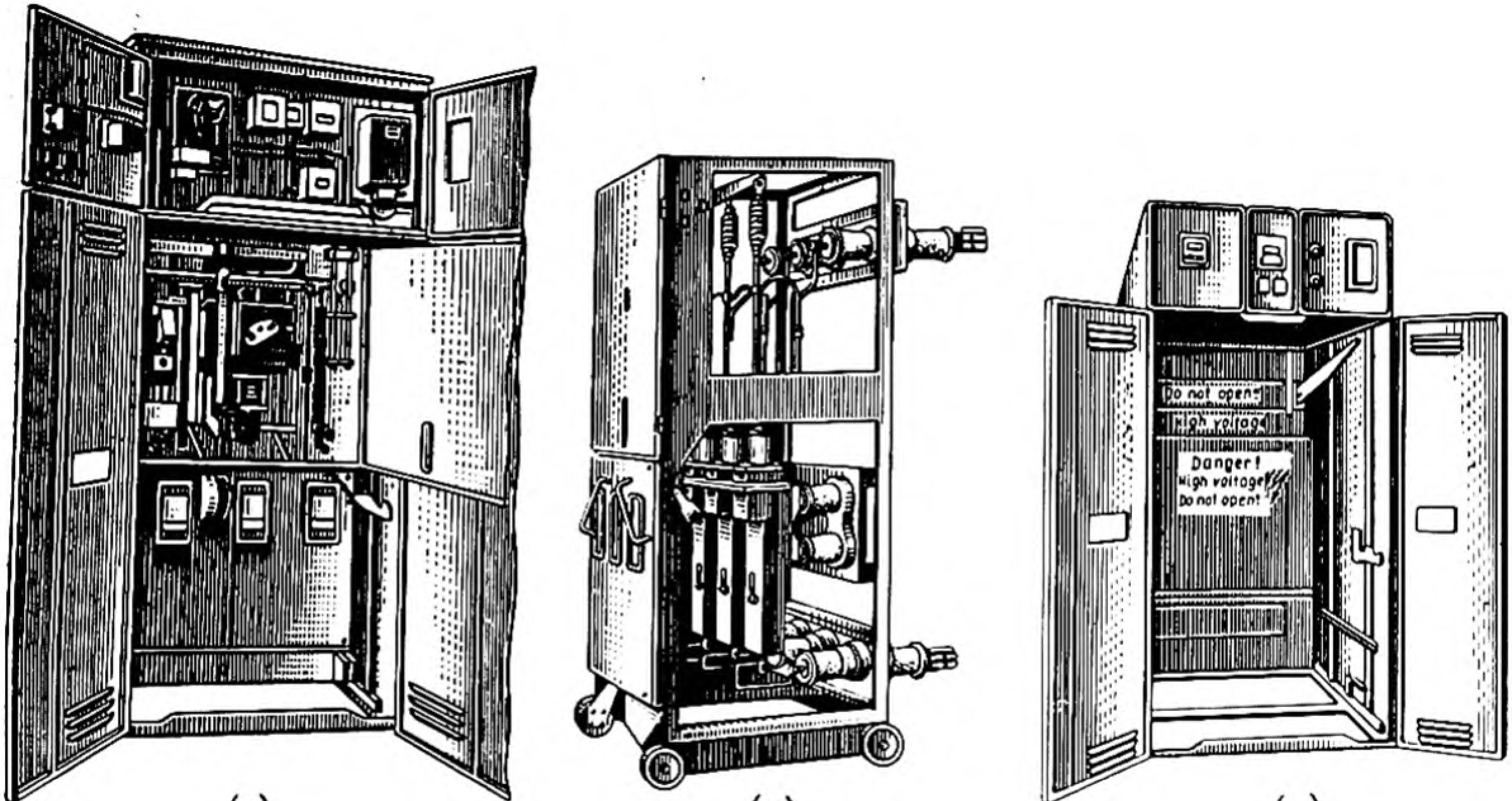
Prior to installation each KPУ unit should be thoroughly inspected for any damage to the metal enclosures, doors, paintwork, etc., and for missing parts against the accompanying packing lists. Next the parts (instruments, relays and buses) shipped separately packed should be examined to make sure that they have not been damaged in transit.

For installation, each KPУ unit is lifted by a crane and moved through a special opening in the switchgear-room wall or through a window opening.

KPУ units should be transported only in a vertical position. Within the switchgear room, they should be moved into position on rollers.

When the necessary hoisting facilities are not on hand at the moment, or, the more so when few men are available, the switch truck may be rolled out to reduce the weight of the unit.

All plastering, concreting, and whitewashing in the switchgear room must be completed before the KPУ units are moved in. On the other hand, the finish floor covering may be laid after switchgear installation.



(a) (b) (c)

Fig. 153. KPY metal-clad switchgear unit:
a—internal view; b—truck and circuit breaker; c—stationary housing without the truck

The metal supports embedded in the floor or ceiling by the builders should be checked for compliance with the drawings.

The embedded supports made from Size 12 channels must above all be precisely horizontal and parallel to one another. The deviation should not exceed 5 mm over the entire length of the support.

The supporting structure is checked by means of a batten placed on both channels and a spirit level put on top of it. The load-bearing surfaces of the channels should be about 5 mm above concrete slab level and 5 mm below finished floor level.

All deviations in the position of the embedded channels must be remedied by the builders, who may weld steel pads to the load-bearing surfaces to make them level.

The embedded channels must be butt-welded and connected to the earthing bus at not less than two places by means of 40×4 mm steel strip.

Now the KPY units may be set up on their sites. The switch trucks may be rolled out to reduce the total weight to be handled.

First the outer unit on either of the ends should be installed, taking care to check it with a plumb-bob for verticality and with a level for horizontality. The unit must stand firmly on its base. If it is shaky, steel pads not thicker than 5 mm may be used to level it off.

The switch truck of the unit should roll out smoothly and stand firmly; the fixed and movable isolating contacts should be precisely in line.

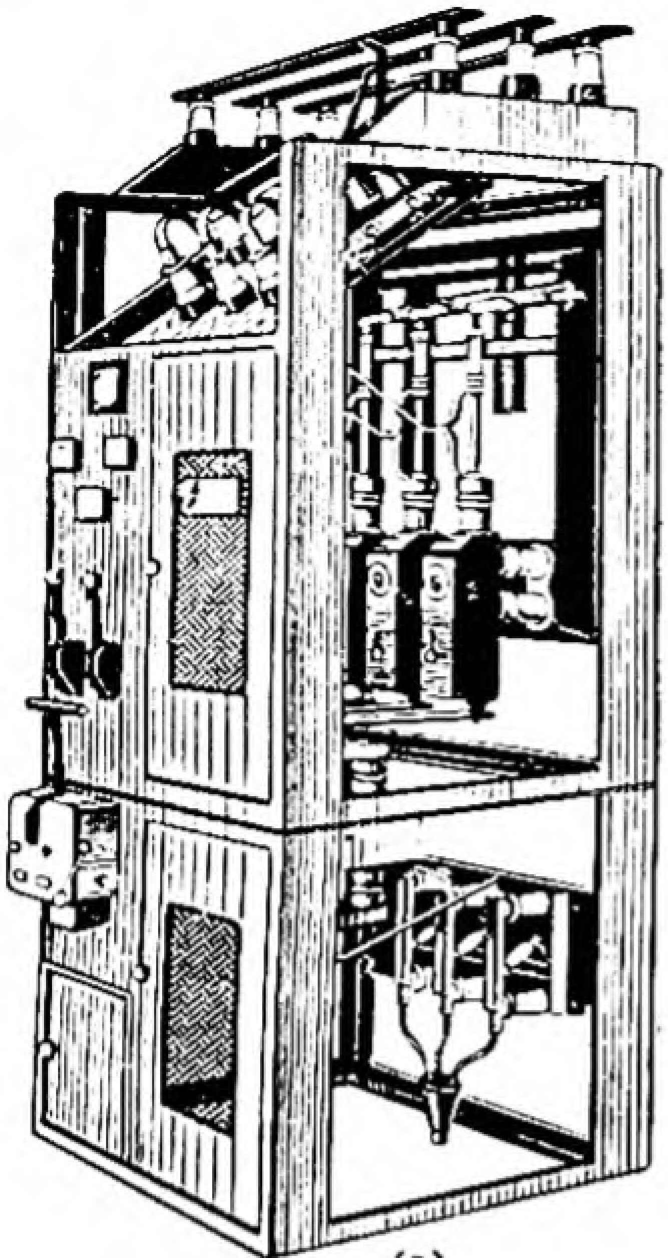
The second unit is then joined to the first one, the third to the second, etc., until all the units in a given switchgear are set up. The units are joined together by M12 bolts. The relative position of the units is checked by means of the red-painted locating holes in the sides. The locating holes of two adjoining units must coincide.

The units are joined up, beginning with an end unit and the one next to it, tightening first the lower and then the upper bolts. When it is necessary to shift a unit slightly in the course of installation, force should only be applied to the underframes because the side walls may otherwise be easily damaged beyond repair.

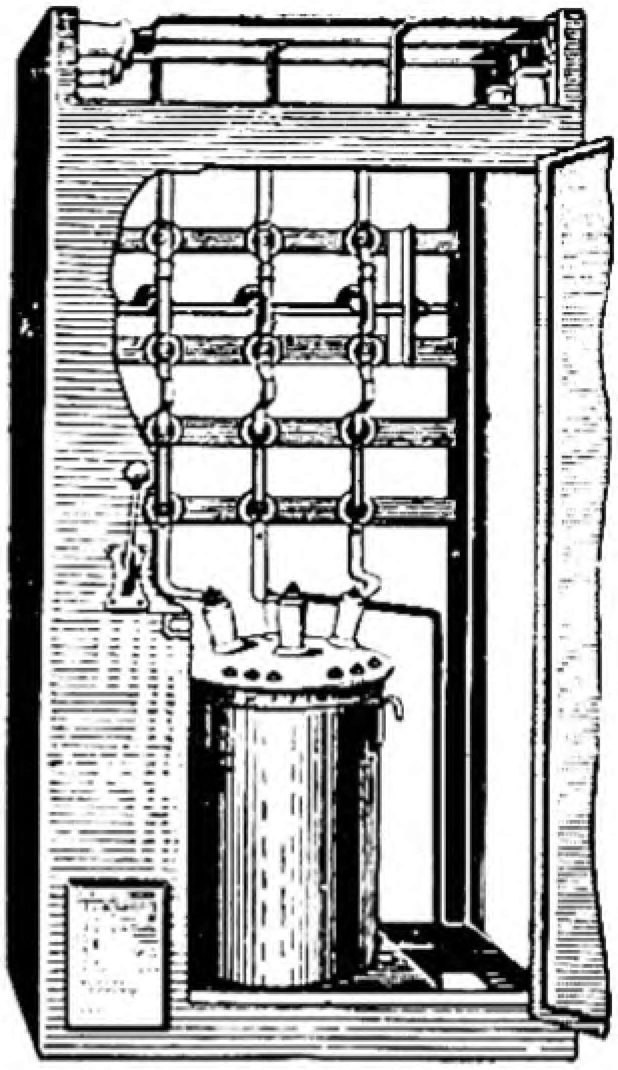
The entire switchgear is then brought into alignment along the front. The units are considered properly aligned if the upper edges of all the doors fall in one line and their fronts are in the same plane, a condition which can be easily checked by a wire strung from end to end.

The underframes of the units are welded to the support channels at four points and the channels are connected to the earthing bus with 40×4 mm steel strip at not less than two points.

Next the primary circuit buses are installed. First, the temporary fastenings provided for transportation are removed from the tee-off



(a)



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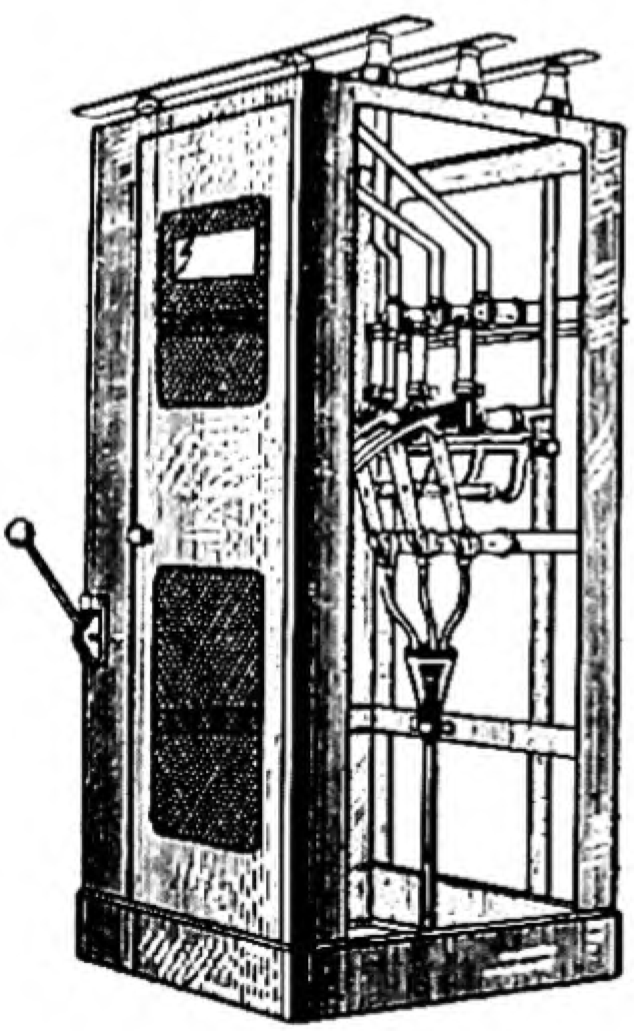


(b)

Fig. 154. KCO prefabricated switchgear units:

a—unit with a ВМГ-133 circuit breaker; *b*—unit with a ВНП-16 load-breaking isolator; *c*—unit with a voltage transformer (НТМИ-10)

buses; the main buses are put in place according to their colour coding (yellow, green, red) and so that the numerals on their ends are the same as those of the switchgear units between which they are to be installed.

Bus sections and tee-offs are bolted together in the manner discussed earlier in this book.

The secondary-circuit buses are unpacked, laid in the ducts and on the cleats provided for them and connected to the terminals according to their numerals. The connections should be checked against the diagram attached to each switchgear unit.

Then the indicating-metering instruments and protective devices are mounted if they have been removed for safety in transit. This will be discussed in Chapter 6, "Installation of Control Circuits".

The equipment in KPY units is earthed through the supporting metal framework. Because of this, the metal under the bolts must be cleaned bright and the bolts fully tightened. This is done after the switchgear units are put in and secured in place. The bus ducts should also be checked to see that they have been snugly fastened to the framework.

Before KPY switchgear may be put into service all the equipment installed in it (circuit breakers, instrument transformers, wiring, etc.) must be tested as outlined earlier.

Mounting of KCO prefabricated stationary-type switchgear. KCO units (Fig. 154) are of a prefabricated type used for assembly of substations and are installed in much the same way as KPY units. The principal difference is that KCO units have no withdrawable trucks.

Problem. Write up an operation sequence for mounting a 10-kv KPY metal-clad unit substation.

CHAPTER 4

INSTALLATION OF OUTDOOR PRIMARY CIRCUIT SWITCHGEAR

24. General

Outdoor substations are intended for high-capacity high-voltage service, generally ranging from 35 to 500 kv. Outdoor switchgear equipment is more complicated in design, bigger and heavier than its counterparts in indoor substations.

This is why a good deal of handling and hoisting is involved at all stages of outdoor substation installation, and the erection site should be equipped with suitable cranes, winches, hoists, drives, etc. (see Sec. 2).

Another distinctive feature of outdoor substations is provision of ample oil-handling and servicing equipment. For, where indoor switchgear uses kilograms of oil, outdoor switchgear requires tons of it.

Outdoor switchgear structures, which include a variety of supports and foundations, are put up by building contractors under the supervision of the electricians.

The primary circuits of any outdoor substation are installed in a sequence which essentially consists of the operations listed below:

(1) marking-out of positions for and construction of supporting structures and foundations;

(2) mounting of support insulators and bushings;

(3) installation of isolators, circuit breakers, instrument transformers, etc.;

(4) installation and connection of buses;

(5) installation and connection of the earthing system.

It is obvious that the actual sequence of installation work may be affected by whether or not the supporting structures are built in time, whether or not the equipment is available, etc. In some cases it will be a good plan to do some of the jobs concurrently. For example,

it is quite possible to combine the installation of the switching equipment and buses or the earthing system.

The actual sequence should therefore take into account the conditions obtaining on the site, giving preference to methods promising economy in time and effort.

25. Marking-out of Positions for Supporting Structures and Foundations

The marking-out of positions for outdoor switchgear must be done by the builders to the layout plans.

The main axes of symmetry of the switchgear site are determined by means of a theodolite, and the elevations of the supporting structures and foundations above the finish grade of the substation site are found with the aid of a surveyor's level.

The main axes of symmetry thus determined are then marked out by stringing steel wires 1.5 to 2 mm in diameter at some height convenient for dropping the centre lines for the equipment.

A foreman or a skilled crew leader should be assigned the job of supervising the work of the builders and checking the actual dimensions and spacings against the drawings. This man should also see to it that the supporting structures and foundations are up to standard in quality and that their dimensions are in keeping with the specifications for the mounting of the equipment.

Examples of supporting structures and foundations for the various switching equipment are discussed below.

26. Mounting of Support Insulators and Entrance Bushings

Support insulators. As in indoor units, support insulators in outdoor substations carry live parts and insulate them from earth and from other pieces of equipment which are at some other potential.

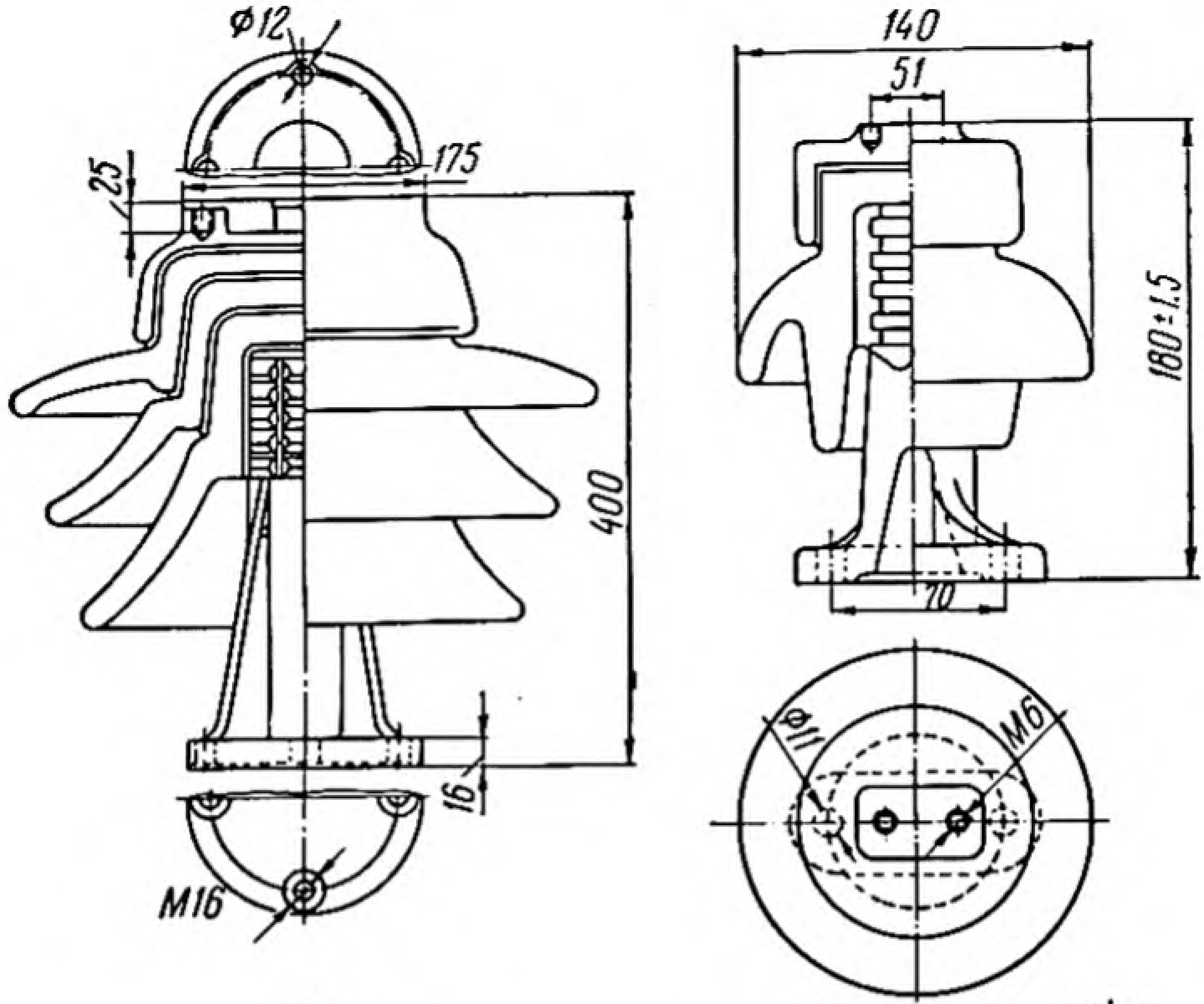
Some of the support insulators used in outdoor substations are shown in Fig. 155 *a* and *b*, and in Table 20.

Table 20

Weight of Several Types of Outdoor Support Insulators

Type	Weight of insulator, kg
ШН-6	2.8
ШН-10	4.1
ШТ-35	35
ИШД-35	41.2

Note: The letters in the type designation of support insulators stand as follows: ШТ for "pin-type"; Н, "outdoor", И, "insulator"; О, "support". The numerals following the letters denote the kv rating.



(a) (b)

Fig. 155. Outdoor support insulators:
a—ИШД-35; b—ШН-10

For working voltages of 110, 220, 400 and 500 kv, ИШД-35 insulators are assembled in a stack consisting of three, four, five or more insulators, depending upon the working voltage. In such cases the insulator stack is designated according to the number of insulators or units it contains. For example, an insulator stack for 110 kv is denoted "3ИШД-35".

Before mounting, support insulators are inspected visually much as indoor insulators are.

The mounting of support insulators on a metal busbar bridge (Fig. 156) provides a typical example. The insulators are secured in place with M16 bolts. The bottom of the insulator flange and the seating surface on the metal framework should be thoroughly cleaned and given a coat of petroleum jelly or grease for protection against corrosion and reliable contact between them. The frame is then connected to the earthing system.

Entrance bushings. These bushings carry the current-carrying parts of an outdoor substation through the walls of an indoor switchgear structure.

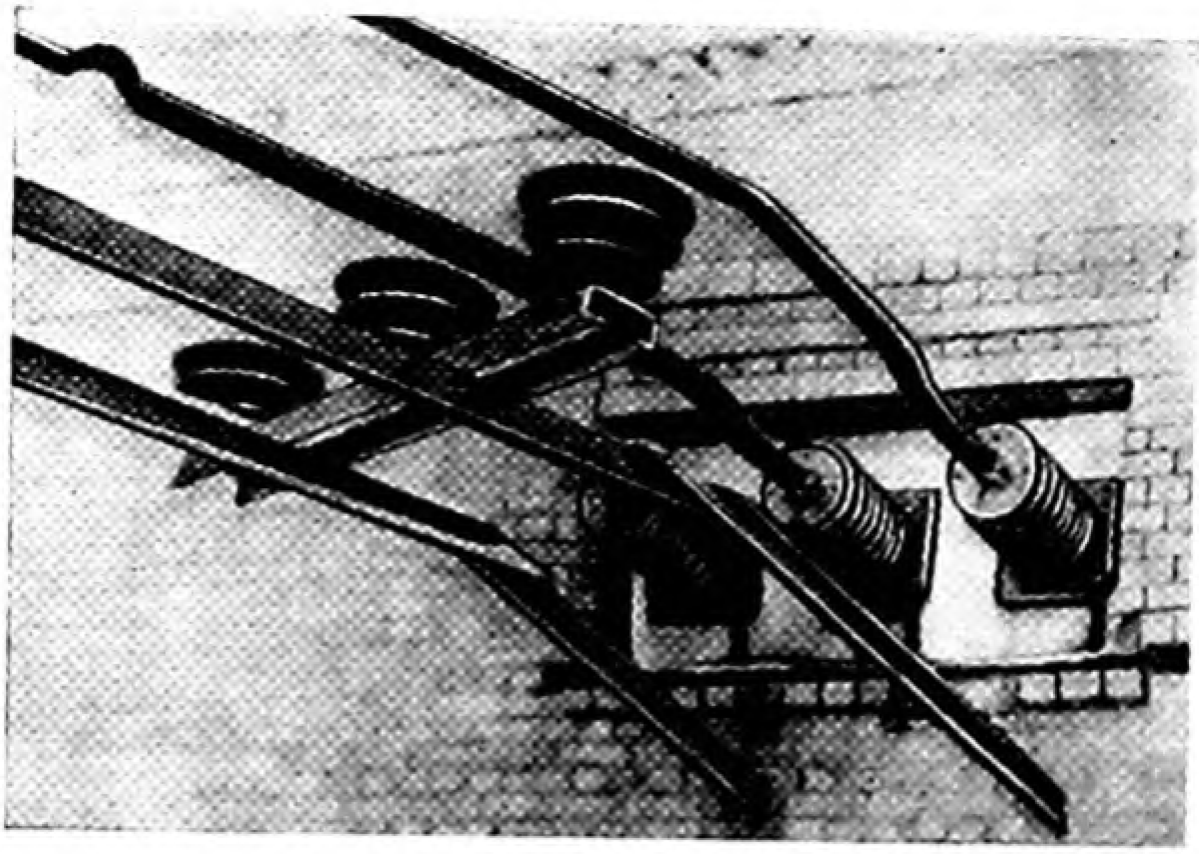


Fig. 156. ИШД-35 insulators mounted on a metal bus bridge

Data on some of the bushings for service from 6 through 35 kv are given in Fig. 157 and Table 21.

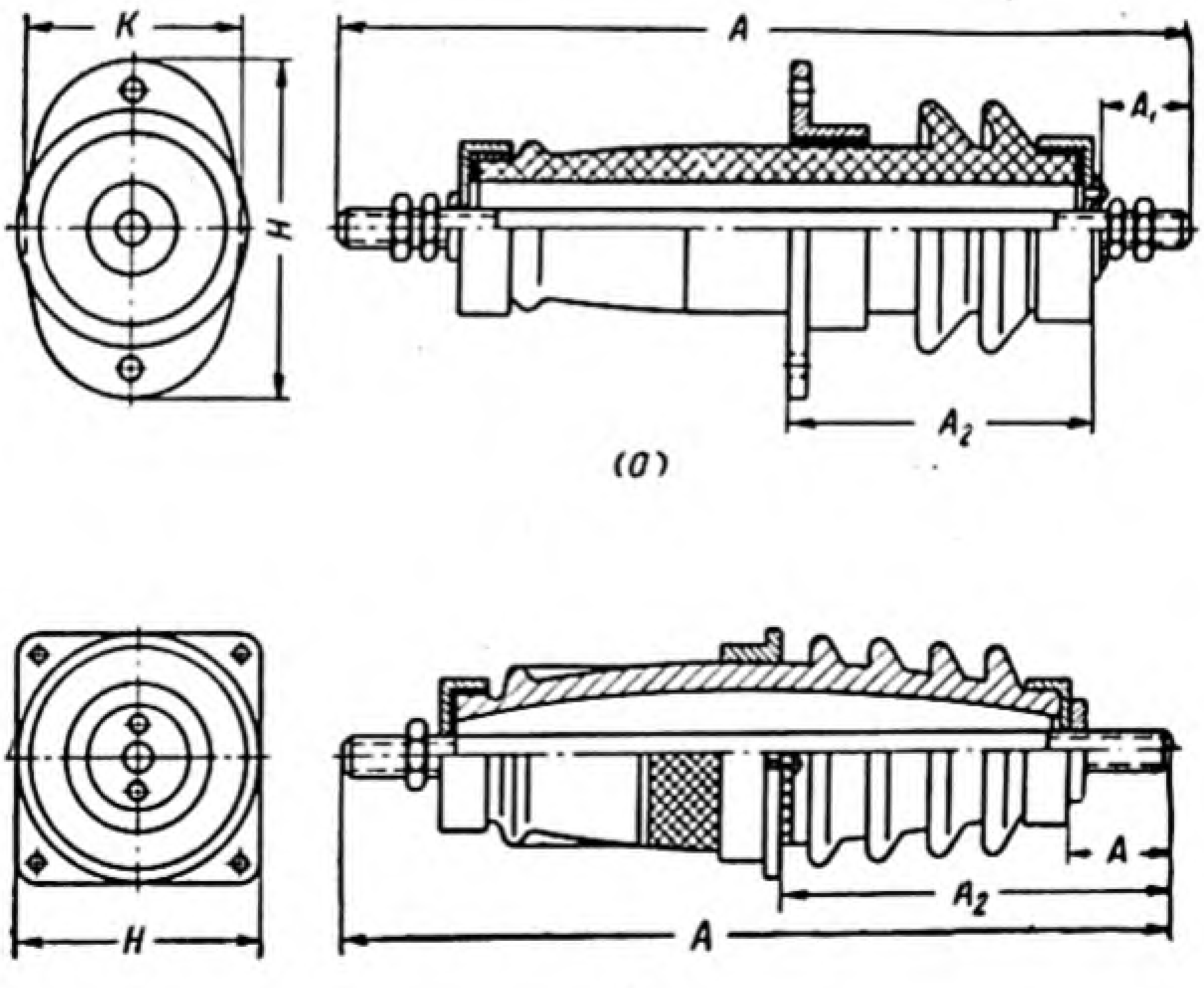


Fig. 157. Outdoor entrance bushings:
a—type ПНБ; *b*—type ПНВ

Table 21

Principal Dimensions and Weight of Several Entrance Bushings

Type	Dimensions (Fig. 157), mm				Weight, kg
	A	A_1	A_2	H	
ПНБ-6/400	530	47	191	175	9.0
ПНБ-6/600	550	57	191	175	9.8
ПНБ-6/1000	580	70	215	175	13.0
ПНБ-10/400	605	47	300	175	9.4
ПНБ-10/600	625	57	240	175	10.0
ПНБ-35/1000	1025	70	250	175	38.9
ПНВ-10/1000	710	70	300	240	20.6
ПНВ-10/1500	710	70	300	240	24.0

For a working voltage of 110 kv, porcelain-shell, oil-filled bushings are used. A general view and the dimensions of one of them are given in Fig. 158. This is an MH-110 bushing weighing 470 kg.

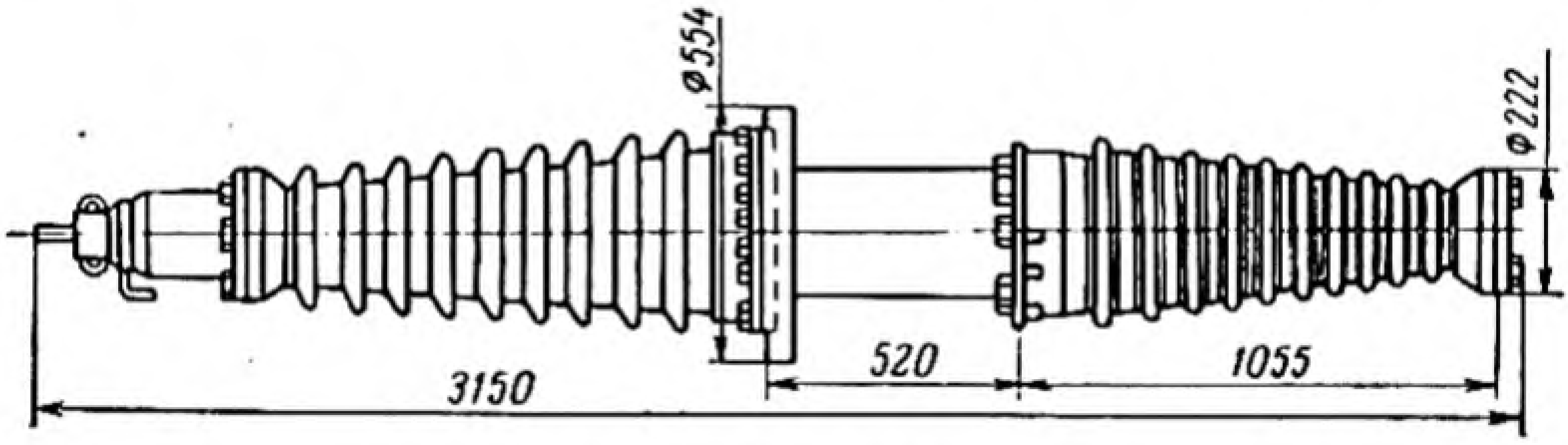


Fig. 158. MH-110 oil-filled bushing

The tolerances for bushings intended for service at up to 35 kv are as follows:

1. Overall length shall be within ±5 mm of the manufacturer's data, with the height from flange to head within ± 3 mm. In the case of greater deviations, the bushings should be grouped into, and used as, sets of like deviation.
2. The offset of the current-carrying rod relative to the bushing axis shall be not more than ±1. In the case of greater deviations, the position of the rod should be corrected by placing of centring washers or by repositioning the caps on the bushings.

If the bakelised sleeve on the central rod shows traces of moisture or the varnish coating is damaged, the rod must be removed and its bakelised sleeve dried out and impregnated with insulating varnish.

110-kv oil-filled bushings should be checked for any leakage of oil. For this, the bushing to be checked is placed in a vertical position on horses or a support rack in a room with a temperature of +15 to +20°C. After 48 hours the bushing is inspected for any traces of oil leakage.

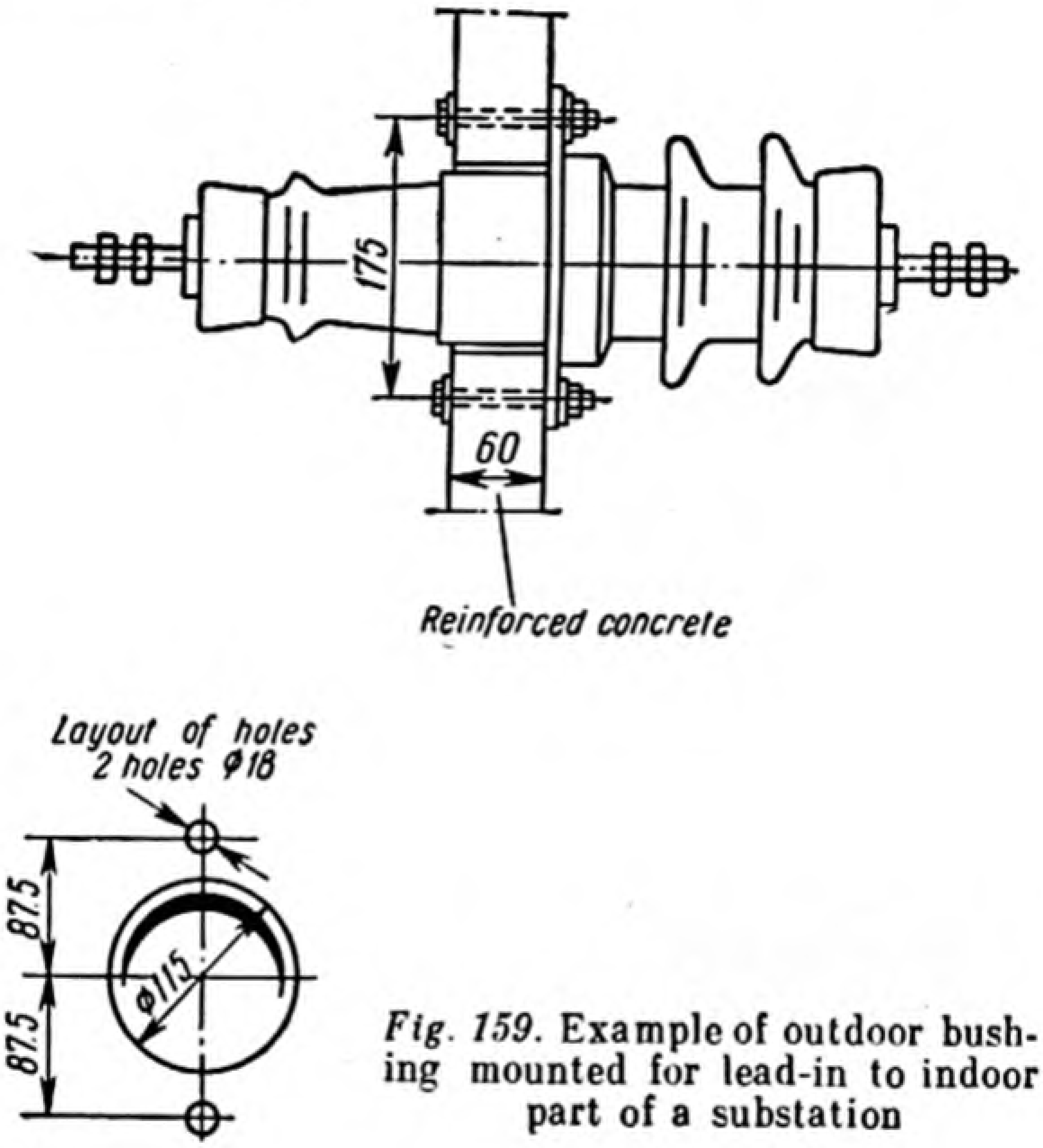


Fig. 159. Example of outdoor bushing mounted for lead-in to indoor part of a substation

If leakage is detected, the bolted joints should be tightened, taking care to tighten each bolt by not more than one-sixth of a turn at a time.

In addition, oil-filled bushings should be tested for air tightness at a pressure of 1.5 atm.

Bushings in the 35-kv class are mounted as explained earlier in Sec. 9.

A typical example of a bushing mounted in an outdoor substation may be seen in Fig. 159.

MH-110 oil-filled bushings are mounted on a steel plate embedded in the wall opening of the switchgear structure. When mounted, the bushing should be at an angle of up to 120 degrees from the vertical. To avoid condensation around the bushing and on its surface,

the mounting plate should be lagged on the inner side (within the switchgear room) with a layer of heat insulation (asbestos, glass wool).

These bushings are lifted into place by eyebolts screwed into their flanges.

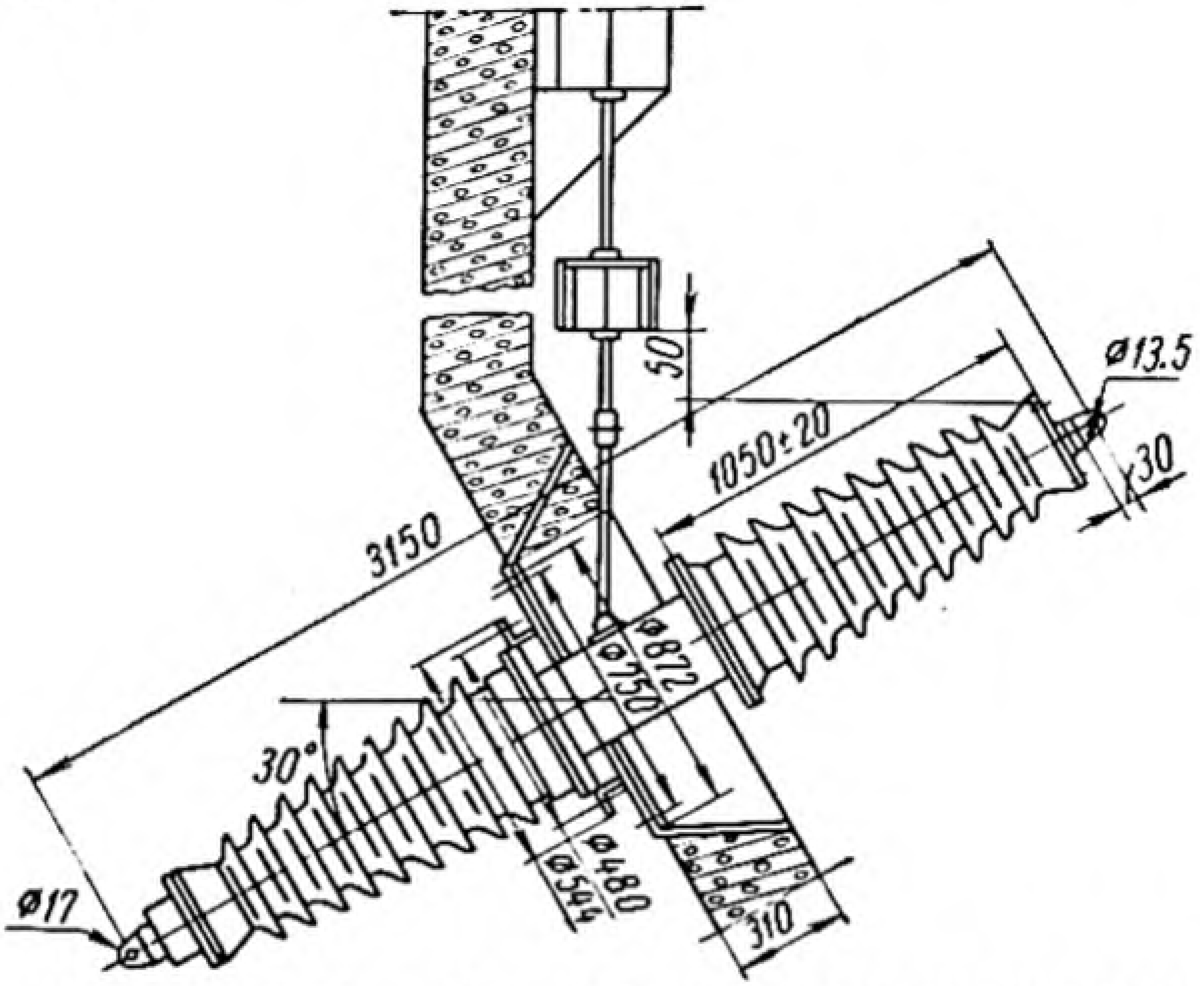


Fig. 160. General view of a mounted MH-110 oil-filled bushing

An MH-110 oil-filled bushing mounted in place may be seen in Fig. 160.

Problem. Write up the mounting of an outdoor ПНБ-10/1000 bushing as shown in Fig. 159.

27. Mounting of Isolators

Isolators in outdoor substations serve the same purpose as those in indoor substations (see Sec. 10).

Some of the isolators used outdoors are illustrated in Figs 161 and 162, while Table 22 gives their weights.

Visual inspection. Isolators received for mounting should be first given a visual inspection for broken porcelain, deformed bases, and missing parts.

РЛН and РЛНЗ isolators come as separate single-pole units ready for mounting and assembly into three-pole units, with the fixed horns detached and secured to the moving contacts.

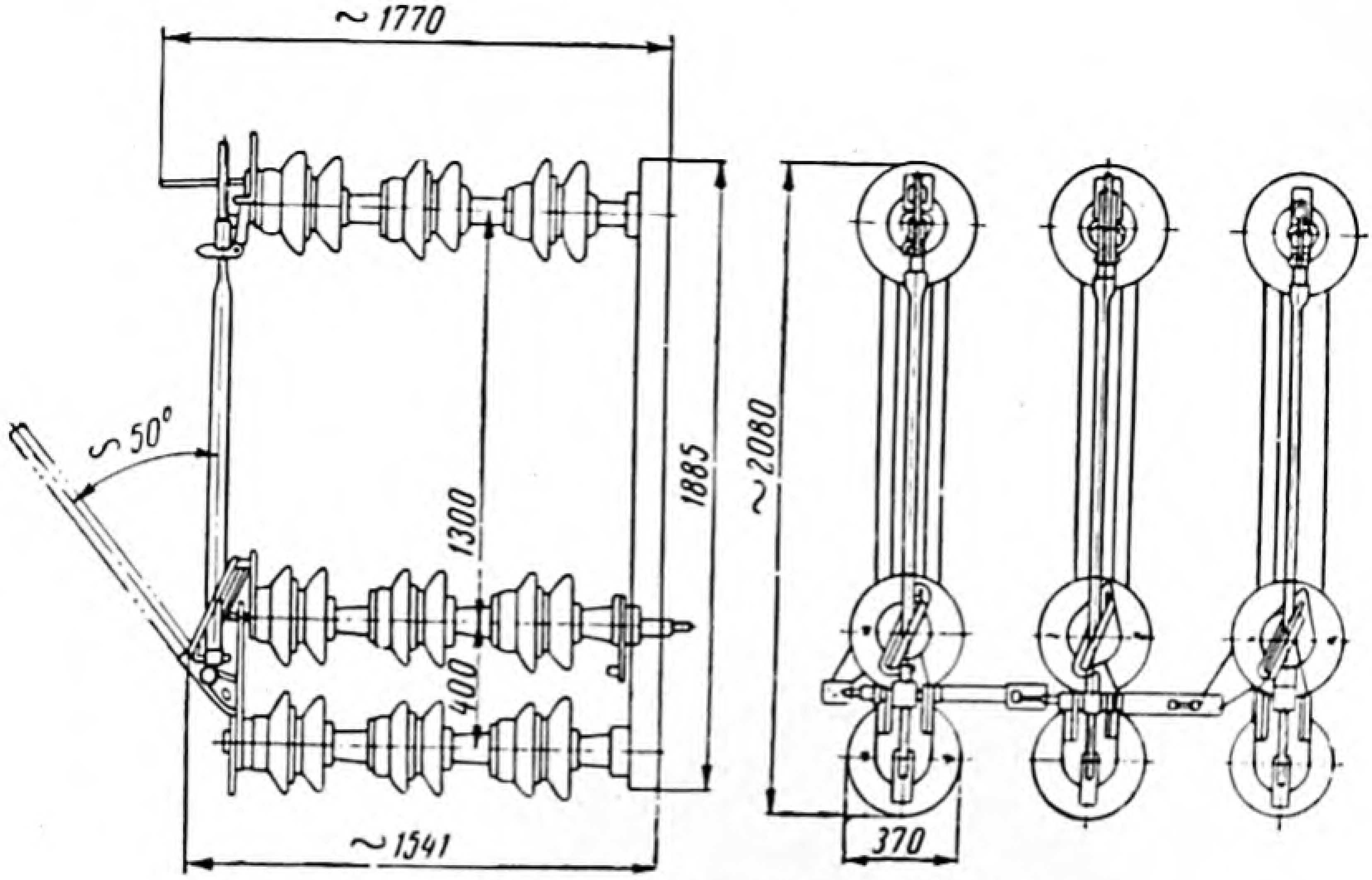


Fig. 161. РЛН-110 outdoor isolator

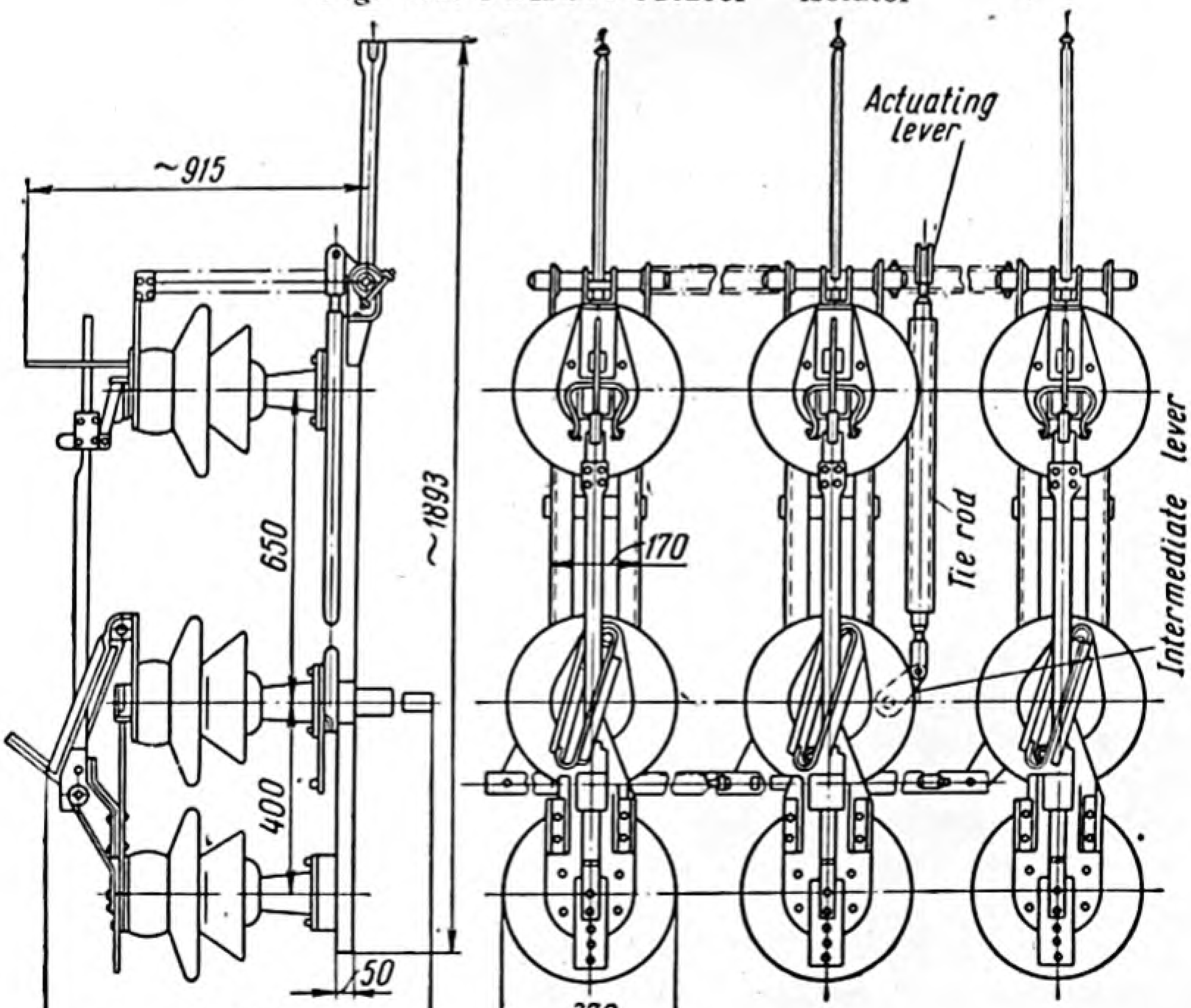


Fig 162. Outdoor isolator provided with earthing blades

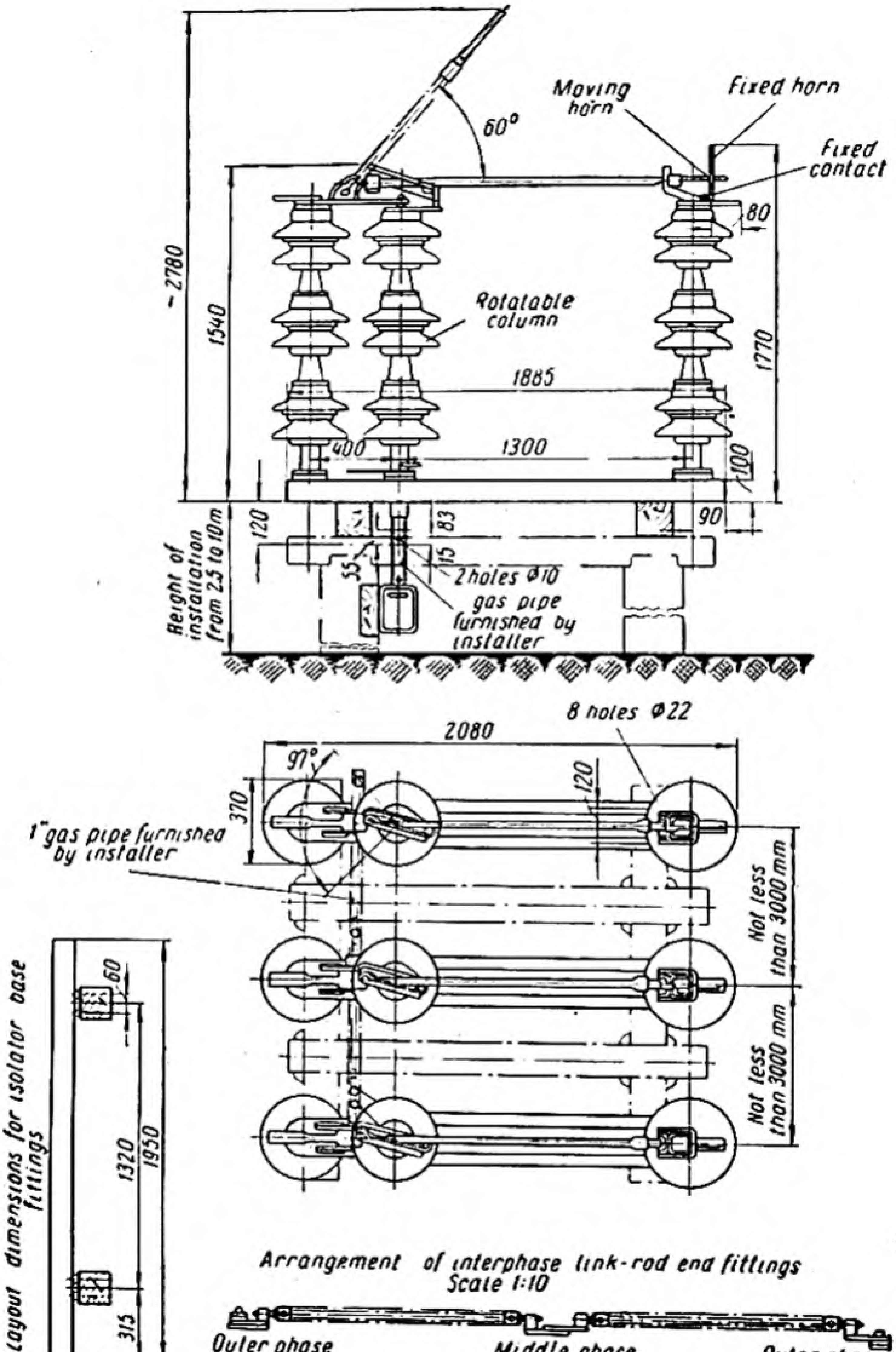


Fig. 163. **Installation drawing for PЛH-110 isolator to be mounted on wooden support structure**

Table 22

Weight of Several Outdoor Isolators

Type	Weight, kg
РЛН-35/1000	431
РЛН3-35/600	435
РЛН-110/1000	1,261
РЛН3-110/1000	1,291

Note: (1) The letters in the type designations stand for: Р for "isolator", Л — "line circuit", Н, "outdoor", З, "earthing blades". The numerator denotes the kv rating, the denominator, the current rating. (2) The weight is given for three poles.

Mounting of an isolator. Isolators may be mounted on a wooden (Fig. 163), a metal (Fig. 164), or a reinforced-concrete support structure. The last two types are more common.

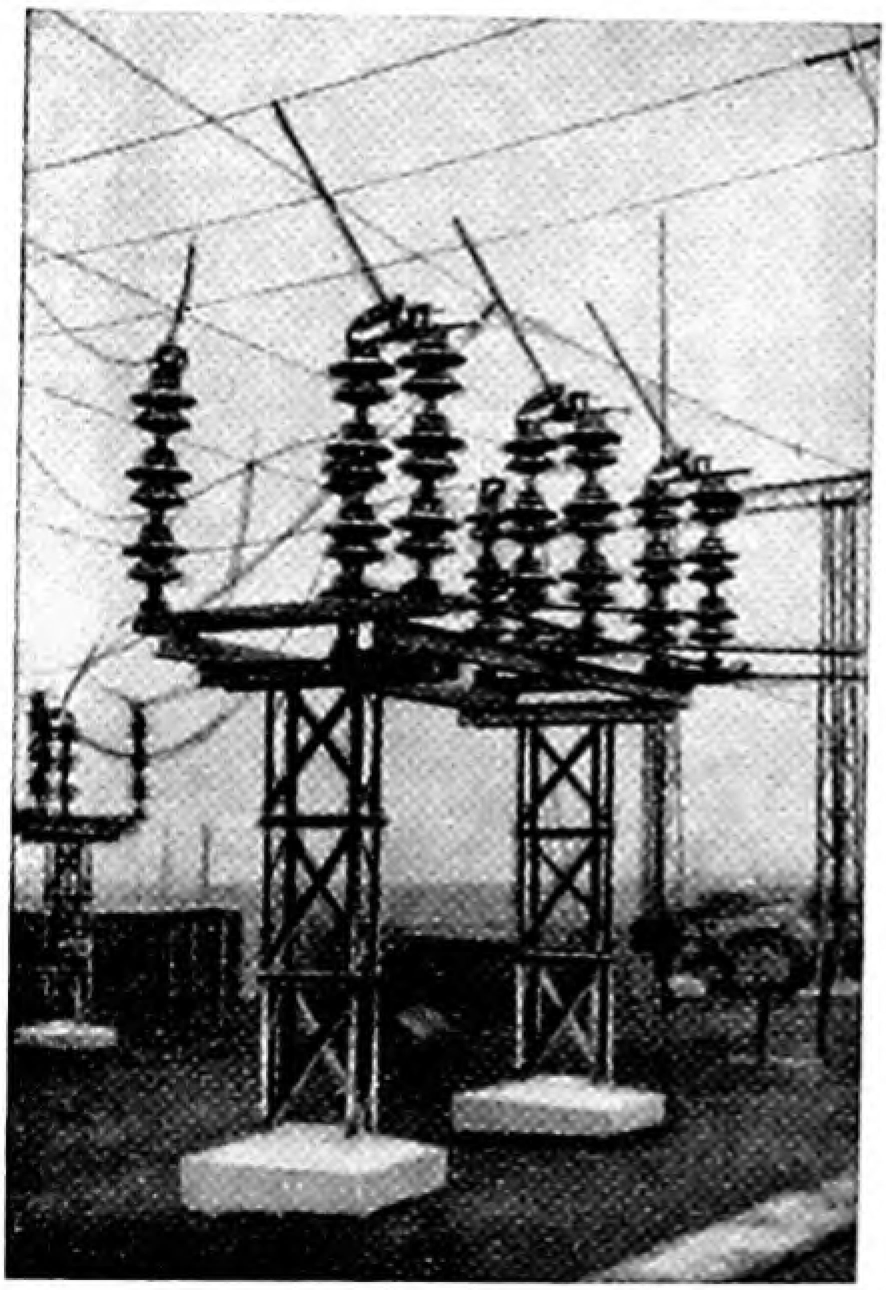


Fig 164. General view of РЛН3-110 isolator mounted on a metal support structure

Each single-pole unit of an isolator is lifted onto its support by a truck crane or an electric hoist and secured in place by bolts varying in size from M18 to M20.

In setting up the pole units, it is necessary to see that the moving contacts correctly enter their fixed contacts. If they do not, the base of the isolator has been deformed.

The moving horn (see Fig. 163) should wipe against the left-hand side of the fixed horn (as viewed from the rotatable column) with slight friction.

When all three single-pole units are in place, they are closed as far as they will go and connected into a three-pole unit. For this, two pieces of one-inch gas pipe cut

to the required length are fitted with the end fittings supplied by the isolator manufacturer (see Fig. 163). The end fittings are secured to the pipe ends by pins prepared from 6 to 8 mm round steel wire. The tie rods thus made are then seated on the pivot studs of the actuating levers in each pole.

Mounting of the operating mechanism and its linkage to the isolator. The РЛН-110 mechanism (Fig. 165) is used to operate РЛН-35 and РЛН-110 isolators. It weighs 11 kg.

РЛН3-35 and РЛН3-110 isolators use ПРН3-35 operating mechanisms 16 kg in weight (Fig. 166).

The isolators are linked with their operating mechanisms by a tie rod made from $1\frac{1}{4}$-inch gas pipe. The pipe is cut to a length which depends upon the height at which the isolator is to be erected (see Fig. 163). This height is specified in the drawings. The operating mechanism is usually mounted some 1.4 metres above the finish grade of the substation.

The pipe is drilled and pinned on the shaft of the middle isolator pole. The operating mechanism is next set up and temporarily aligned to fit the pipe. In the meantime the lever of the operating mechanism should be in the closed position, i. e., turned clockwise until the latch snaps into its left-hand limit recess (see Fig. 165). The lower end of the pipe, marked out for drilling by that time, is drilled and pinned on the operating-mechanism shaft. The pins may be made from round steel 6 to 8 mm in diameter.

Now the operating mechanism is plumbed and finally secured in its permanent position. The lever of the mechanism may now be turned counterclockwise to raise the moving contacts of the three isolator poles through an angle of not less than 50 degrees in РЛН-35 isolators, and not less than 57 degrees in РЛН-110 isolators, which also applies to РЛН3-35 and РЛН3-110 isolators. With the moving contacts thus positioned, the right-hand limit recess is reached and the lever latch is free to enter the stop recess and lock in this position.

The auxiliary switch of the operating mechanism is mounted so that the cams operating the "open" signal are fully closed when the operating mechanism is in the open position.

The cam controlling the "closed" signal is set at the manufacturer's works and should be fully closed when the operating mechanism is in the closed position.

Mounting of РЛН3 isolators. When РЛН3 isolators are mounted, two lengths of one-inch gas pipe should be slipped onto the ends of the earthing-blade shafts before the pole units are secured in place. Each pipe should be cut to suit the actual distance on the site. The

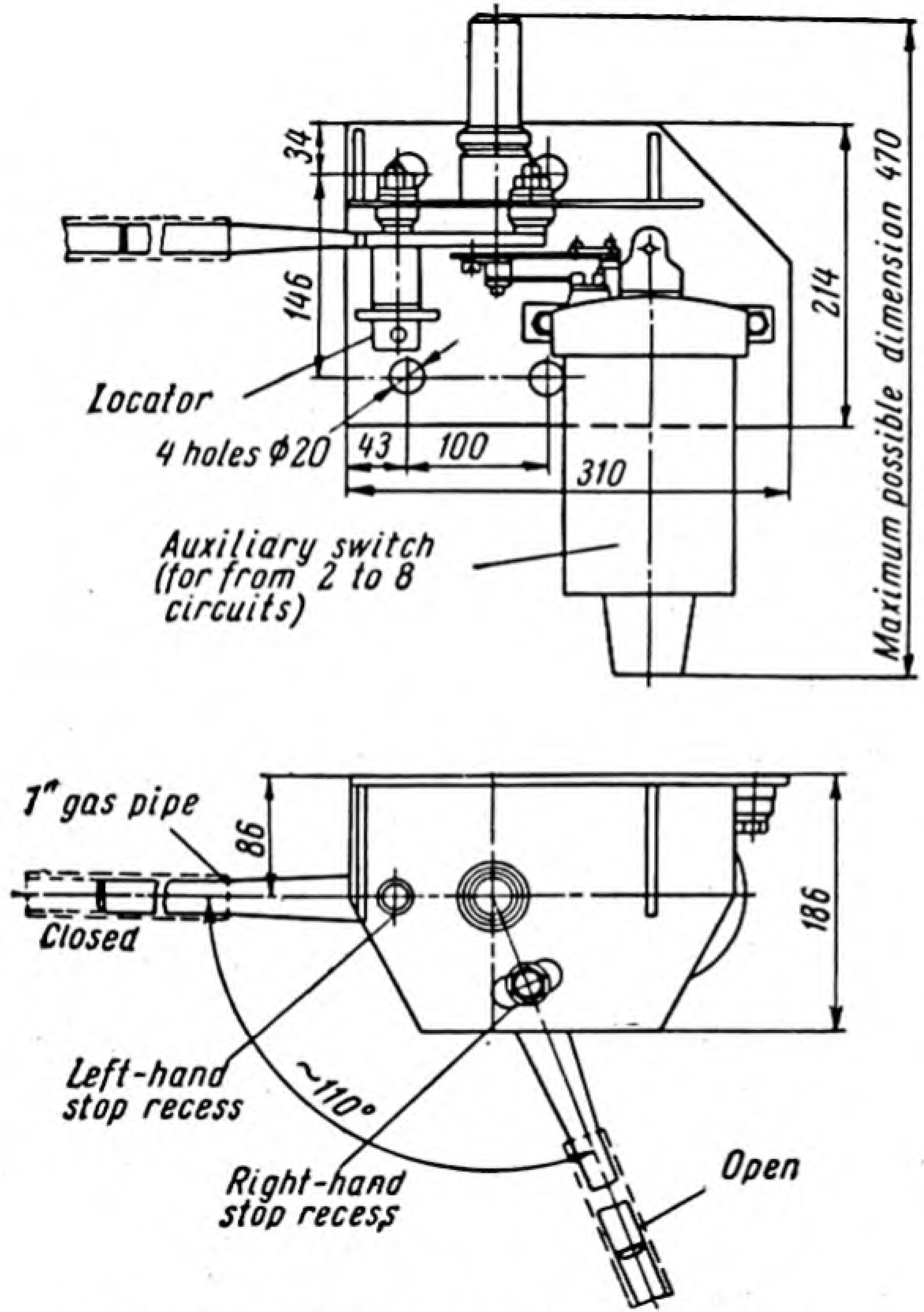


Fig. 165. ПРН-110 operating mechanism

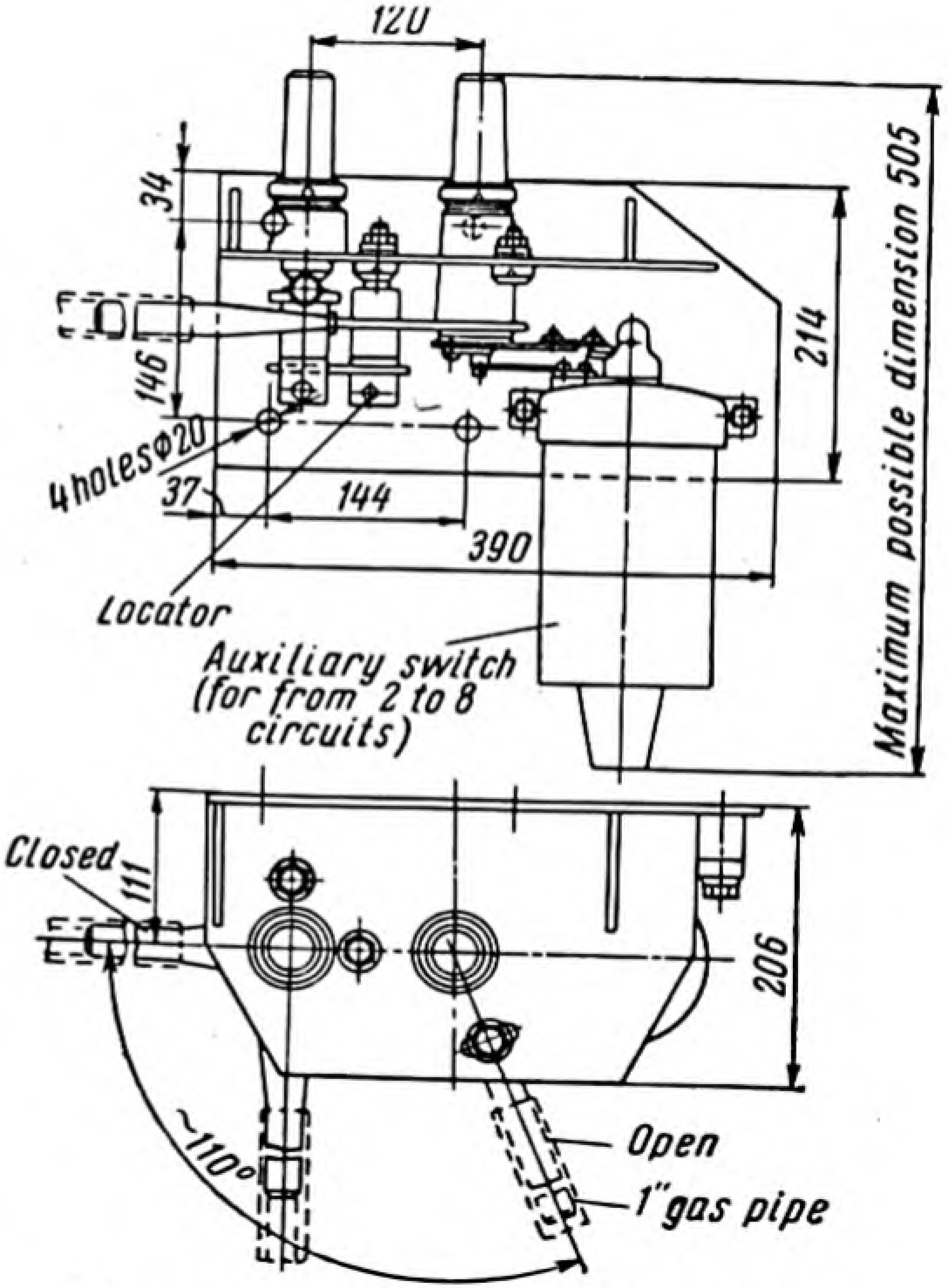


Fig. 166. ПРНЗ-35 operating mechanism

pipe ends should be marked out for drilling and drilled to match the holes in the shafts where the pipes are to be fitted.

The actuating lever (see Fig. 162) supplied with the isolator is fitted on one of the above pipes, the three earthing blades are closed, and the pipes are fastened on the shafts with the bolts supplied by the manufacturer, using the holes drilled in the pipes. The actuating

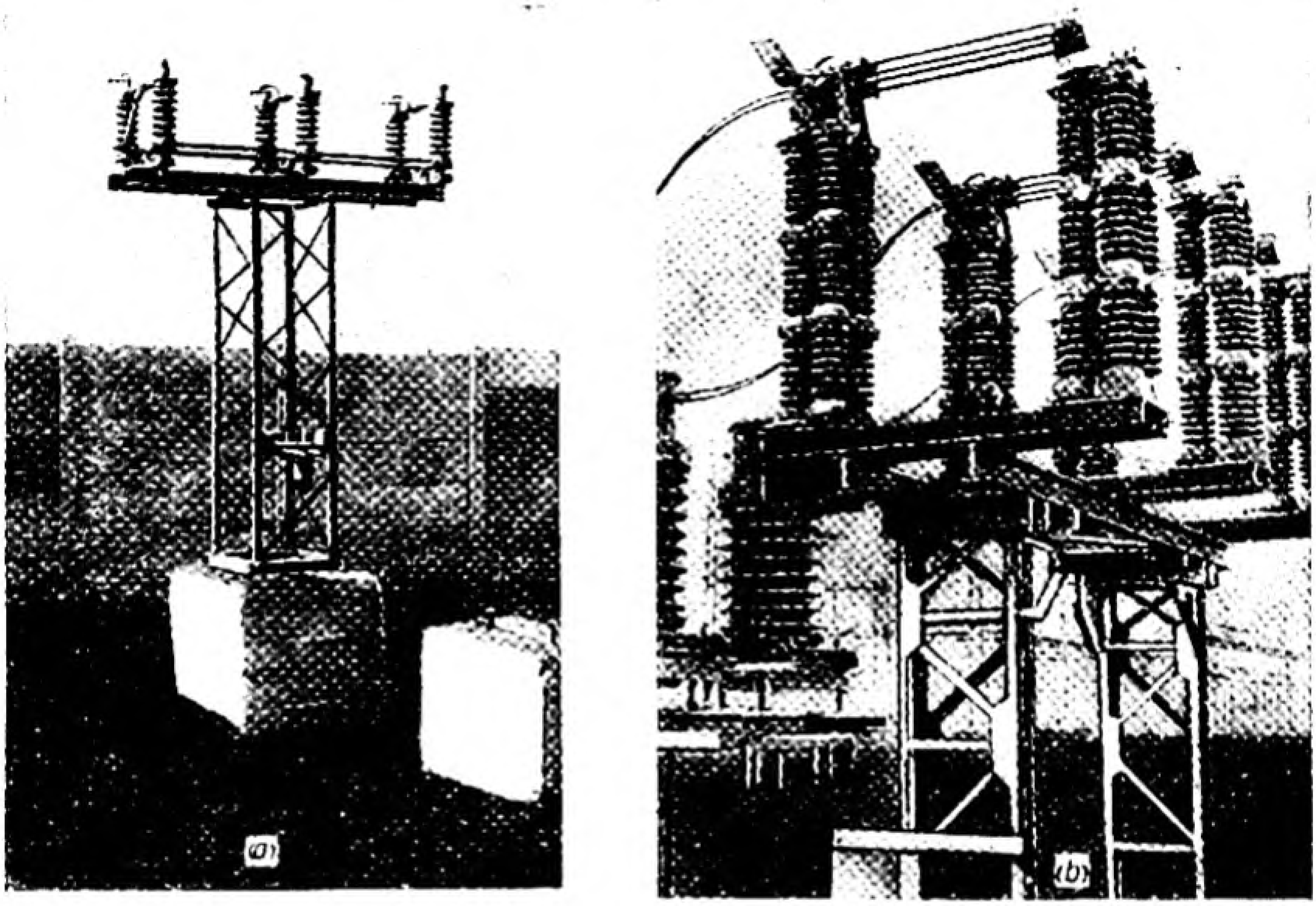


Fig. 167. Isolator installation:
a—РЛНД two-column pole; *b*—РОН isolator fitted with counterweights

lever should be so mounted that its middle is 200 mm away from the centre line of the middle pole and makes an angle of 45° with the vertical towards the rotating insulator. Then the lever and its pipe are drilled together, and a pin of 6 or 8 mm dia is driven in the common holes. The actuating lever is then coupled with the intermediate arm by means of the link rod supplied by the manufacturer. The link rod should be adjusted so that the axis of the intermediate arm makes an angle of 45 degrees with the pole axis.

The intermediate-arm shaft is connected to the auxiliary shaft of the operating mechanism by a $1\frac{1}{4}$-inch gas pipe. The tie rods for actuating the contact blades are fitted with the operating mechanism lever in the closed position.

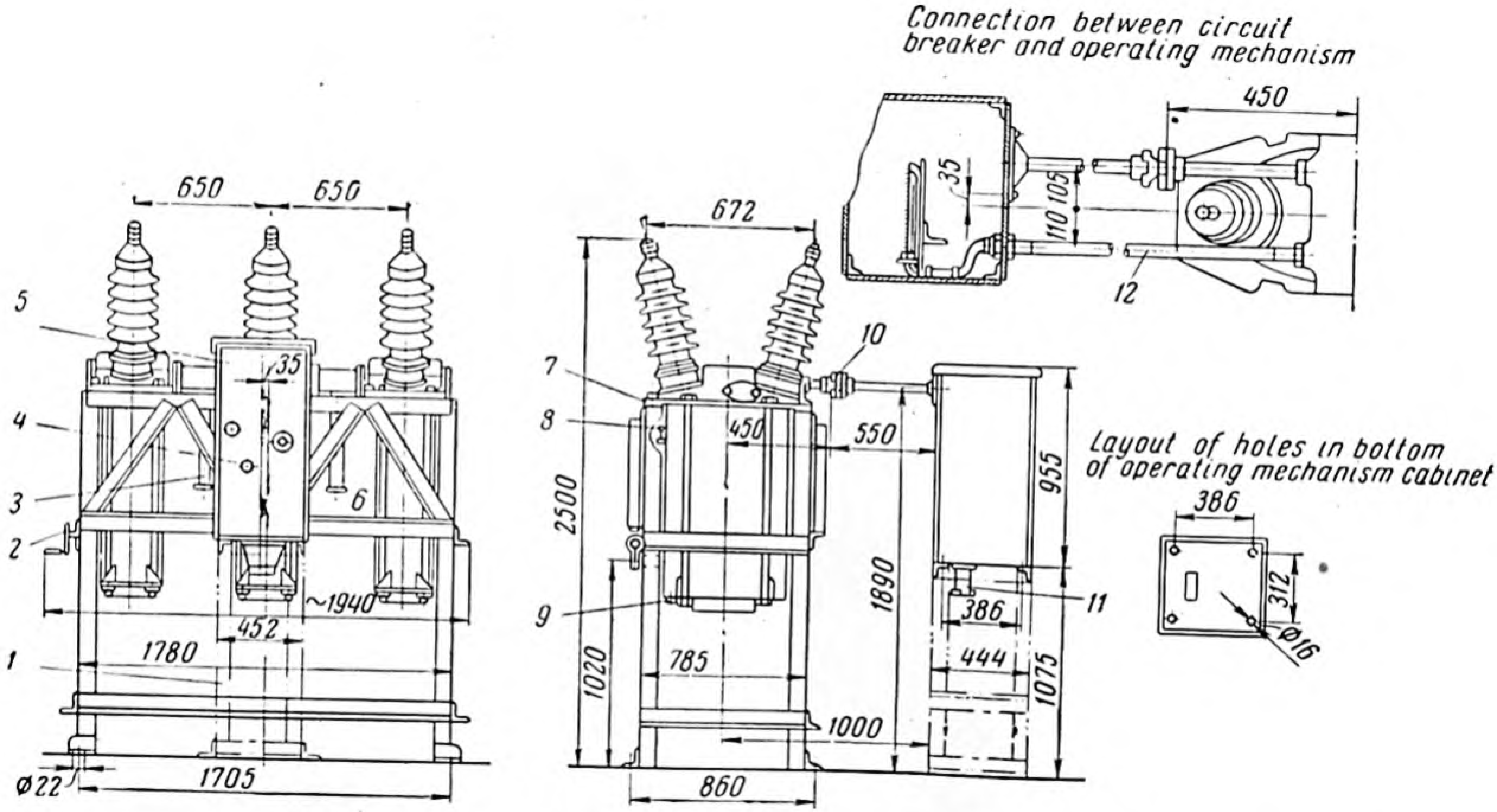


Fig. 168. **General view and installation dimensions of the BM-35 oil circuit breaker:**

1—operating mechanism support; *2*—detachable winch for lifting and lowering oil tanks; *3*—gas vent pipe; *4*—manual trip device; *5*—cabinet containing operating mechanism; *6*—relief valve; *7*—top plate; *8*—oil level gauge; *9*—oil drain cock; *10*—joint coupling; *11*—cable box; *12*—conduit pipe for small wiring from current transformers

After erection of the isolator and operating mechanism all rubbing parts should be lubricated and several trial closing and opening operations performed to make sure that all the units operate properly.

In addition to РЛН and РЛНЗ isolators, use in outdoor substations is made of РОН and РЛНД (Д standing for "two-column") isolators shown in Fig. 167.

Problem. List the operations performed in mounting an outdoor РЛН-110 isolator as shown in Fig. 163.

28. Mounting of Type ВМ-35 and ВМД-35 Oil Circuit Breakers

Among the various types of oil circuit breakers used in outdoor substations operated at up to 35 kv are the ВМ-35 and ВМД-35 oil circuit breakers. The letter "Д" in the latter type designation signifies that its bushing current transformers are provided for differential protection.

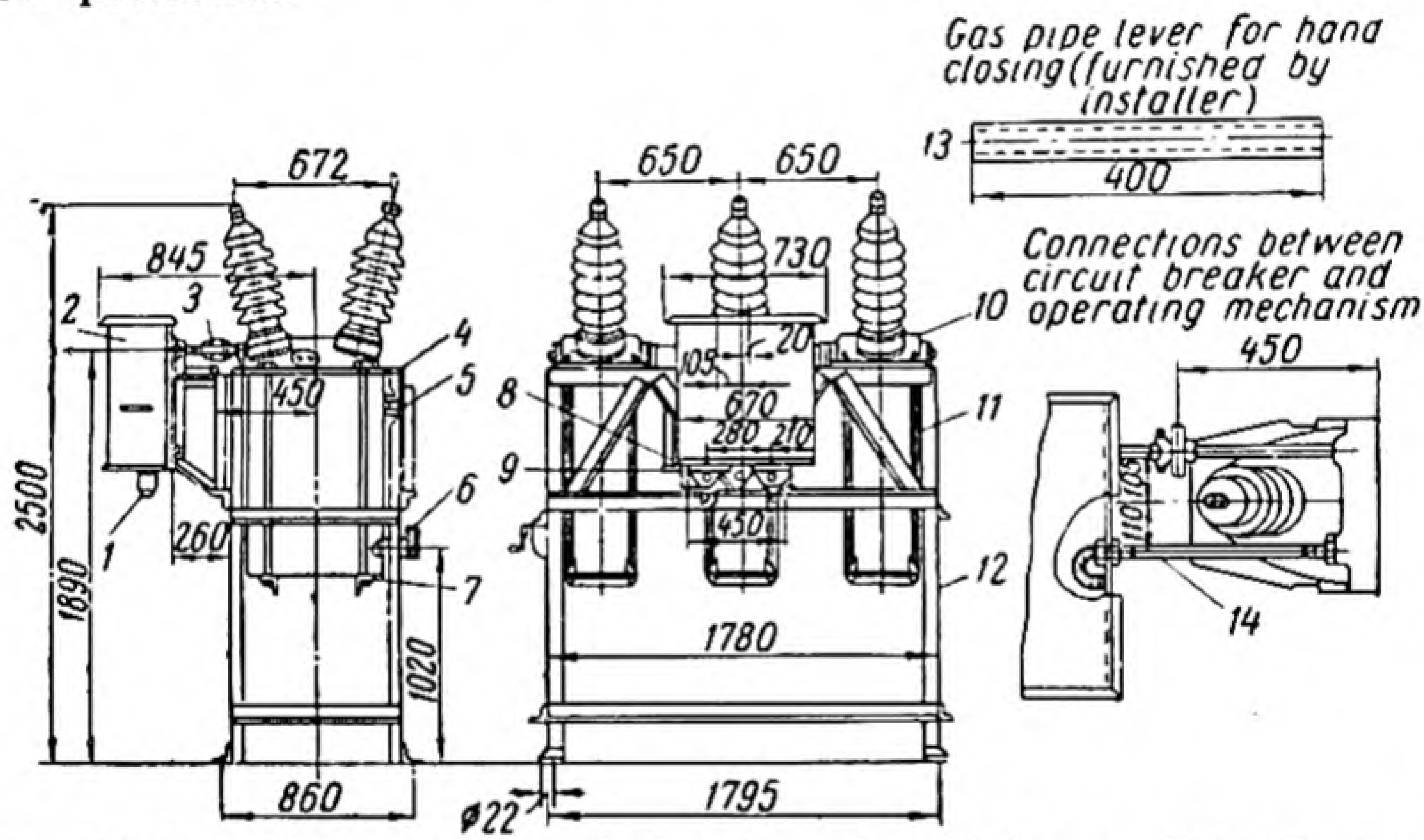


Fig. 169. General view and installation dimensions of the type ВМД-35 oil circuit breaker:

1—cable box; *2*—cabinet containing operating mechanism; *3*—joint coupling; *4*—earthing bolt; *5*—oil level gauge; *6*—winch; *7*—oil drain valve; *8*—manual trip device; *9*—gas vent pipe and relief valve; *10*—top plate; *11*—tank; *12*—framework; *13*—manual-operation gas-pipe lever; *14*—conduit pipe for current transformer small wiring

Both ВМ-35 and ВМД-35 oil circuit breakers are shipped by the manufacturer complete with their operating mechanisms. The former uses an outdoor ШНР-35 cabinet-housed, lever-type mechanism, and the latter, an outdoor ШПС-10 cabinet-housed, solenoid-type operating mechanism.

The installation data for the above equipment are given in Figs 168 and 169.

A BM-35 breaker and its operating mechanism weigh 1,045 kg. The total weight of the ВМД-35 breaker and its operating mechanism is 1,025 kg. In both cases the weights are given dry. Each breaker takes 300 kg of oil.

The two breakers are identical in internal construction. Fig. 170 shows a cross section through a phase of these circuit breakers.

Take-down inspection prior to mounting. After unpacking, each circuit breaker received for mounting, must be thoroughly inspected for possible damage in transit, especially for broken porcelain bushings.

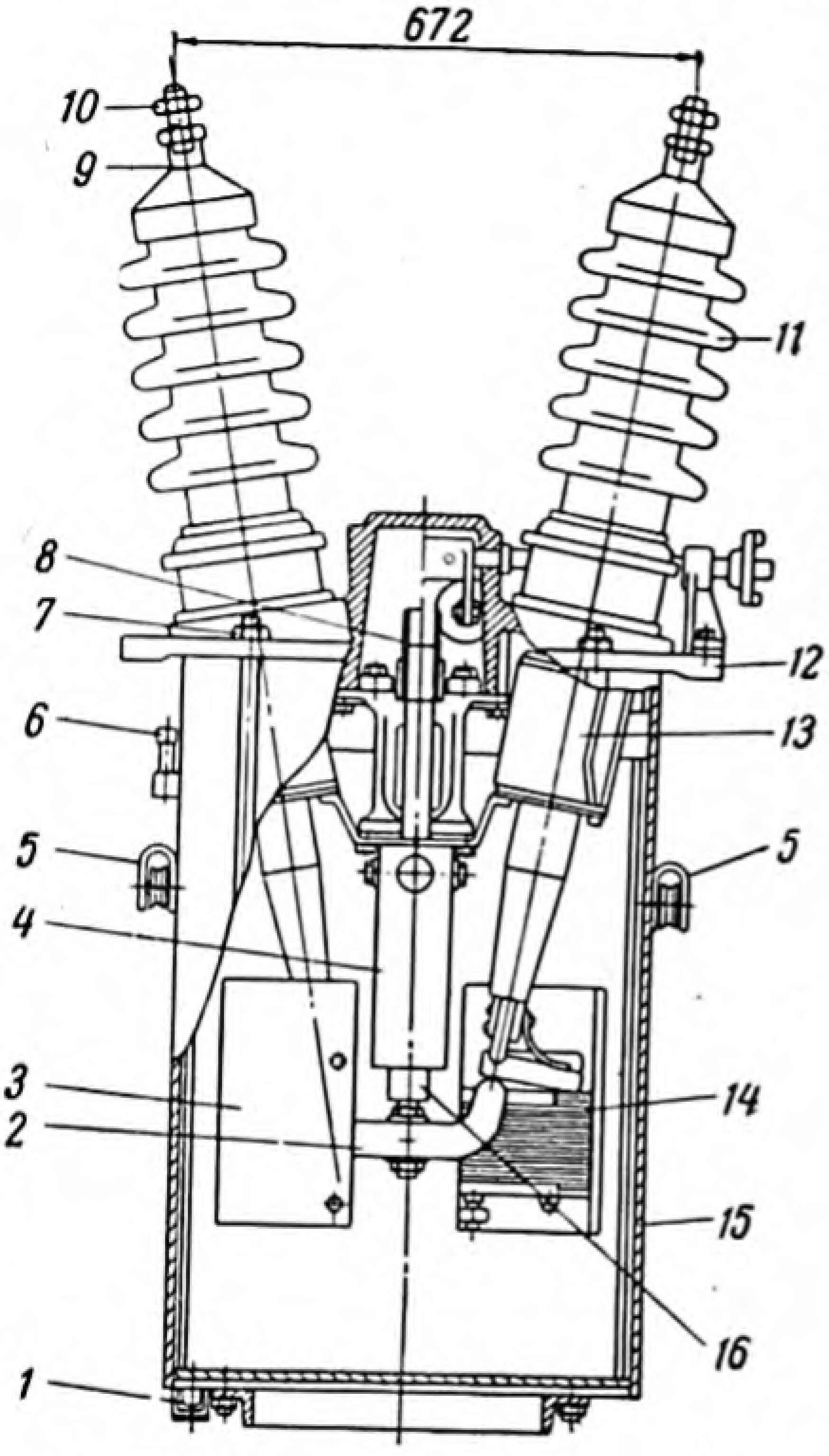


Fig. 170. Sectional view of one phase in a BM-35 (ВМД-35) oil circuit breaker:

1—oil drain valve; *2*—cross-arm and moving contacts; *3*—shield; *4*—guide tube; *5*—tank lowering sheaves; *6*—oil level gauge; *7*—nut; *8*—actuating linkage; *9*—bushing conductor rod; *10*—nut; *11*—bushing shell; *12*—top plate; *13*—current transformer; *14*—axial-blast arc-control chamber; *15*—tank; *16*—insulating lift-rod

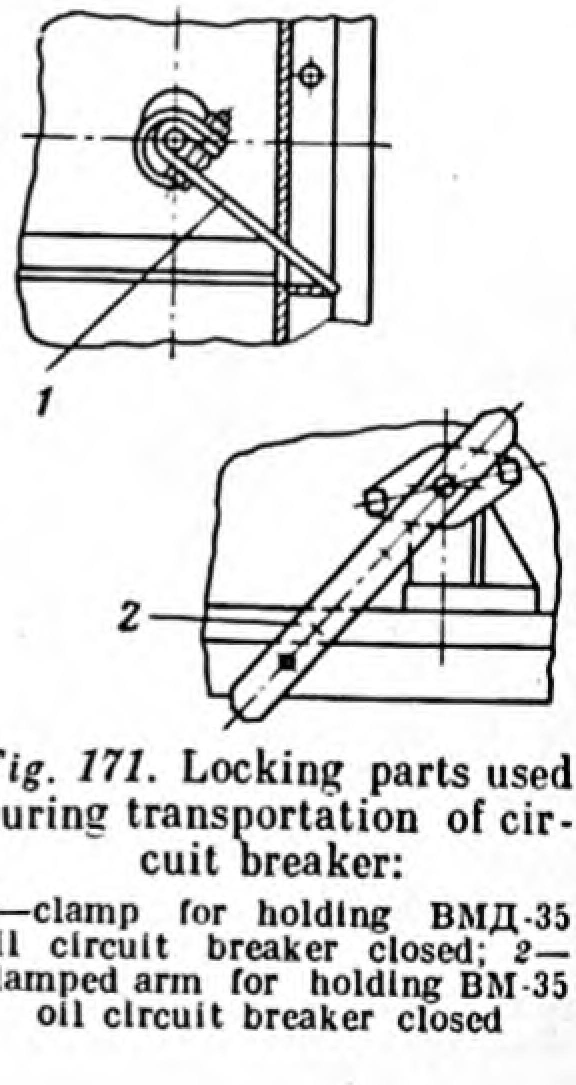


Fig. 171. Locking parts used during transportation of circuit breaker:

1—clamp for holding ВМД-35 oil circuit breaker closed; *2*—clamped arm for holding BM-35 oil circuit breaker closed

In addition, the breaker should be given an internal inspection. For this, the breaker tanks are lowered by means of a winch *2* (Fig. 168) and a wire rope passed over sheaves *5* (Fig. 170). Before a tank can be lowered, the wire rope is first slightly pulled taut by the winch, the nuts *7* (Fig. 170) are unscrewed, and the tank is lowered

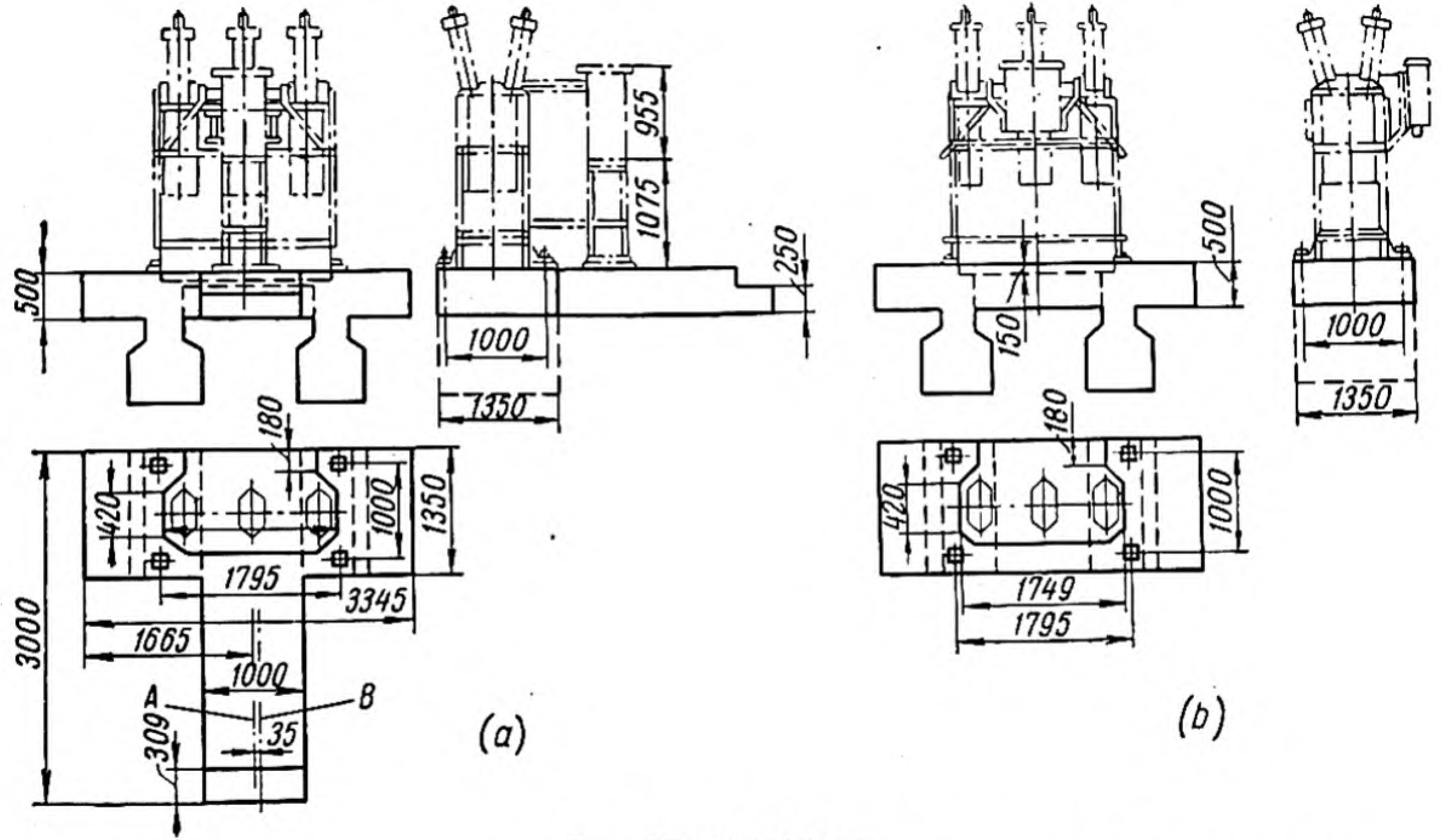


Fig. 172. **Foundations:**

a—for BM-35 breaker: *A*—centre line of operating mechanism; *B*—centre line of breaker; *b*—for ВМД-35 breaker

onto wooden boards placed on the ground. The circuit breaker is next carefully opened by removing the clamped arm *2* on a BM-35 circuit breaker and the clamp *1* on a ВМД-35 circuit breaker (Fig. 171), provided for transportation purposes.

The internal inspection should be concentrated on the condition of the insulating parts (tank insulation, bakelised sleeves, barriers, etc.), actuating linkage, and contacts.

The operating mechanism is inspected for the condition of the auxiliary interlocking switch contacts and for connection of the leads to the terminal blocks. The parts of the operating mechanism and the auxiliary switch contacts are also wiped with a clean dry rag and then given a thin coat of petroleum jelly.

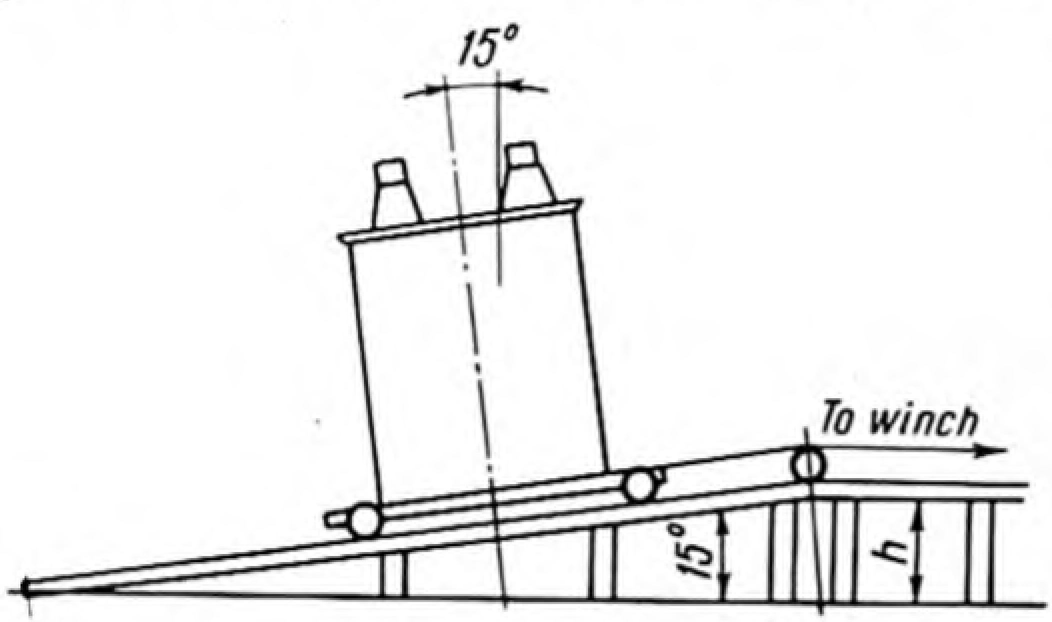


Fig. 173. Raising of apparatus by use of a ramp

It is good practice to give the circuit breaker a trial manual operation. For this, a steel bar 50×5 mm up to 1.5 m long is inserted in the fork on the BM-35 breaker shaft, or a piece of $1\frac{1}{4}$-inch pipe is slipped on the operating mechanism lever of the ВМД-35 circuit breaker.

When circuit breakers are not to be installed in their permanent positions at once, they should be stored in locations sheltered from snow and rain. It is good practice to clean and dry out the tanks and then fill them with dry oil before they are placed in storage.

Mounting of the circuit breaker and its operating mechanism. BM-35 and ВМД-35 oil circuit breakers are lifted on their foundations by a truck crane and secured to the foundation by M20 bolts. Fig. 172*a* suggests a foundation for BM-35 circuit breakers and Fig. 172*b*, for ВМД-35 circuit breakers.

The circuit breakers may also be moved onto their foundations by means of a ramp, as shown in Fig. 173, and an electric winch.

The operating mechanism is then mounted on a pedestal and coupled to the circuit breaker by a detachable joint coupling (Fig. 174) in the following order:

1. The circuit breaker and the operating mechanism are closed; the coupling fork, intermediate fork, and the coupling disk of the joint coupling are put on the shaft in that order; the shafts of the operating mechanism and circuit breaker are brought together and

the coupling parts on the operating mechanism are shifted towards the breaker shaft until the coupling disk engages with the fork on the breaker shaft and an axial gap of up to 2 mm is left between the coupling and intermediate forks.

2. The adjusting screws on the intermediate fork are set so that the least clearance is on the side opposite the direction of rotation of the fork on a closing stroke.

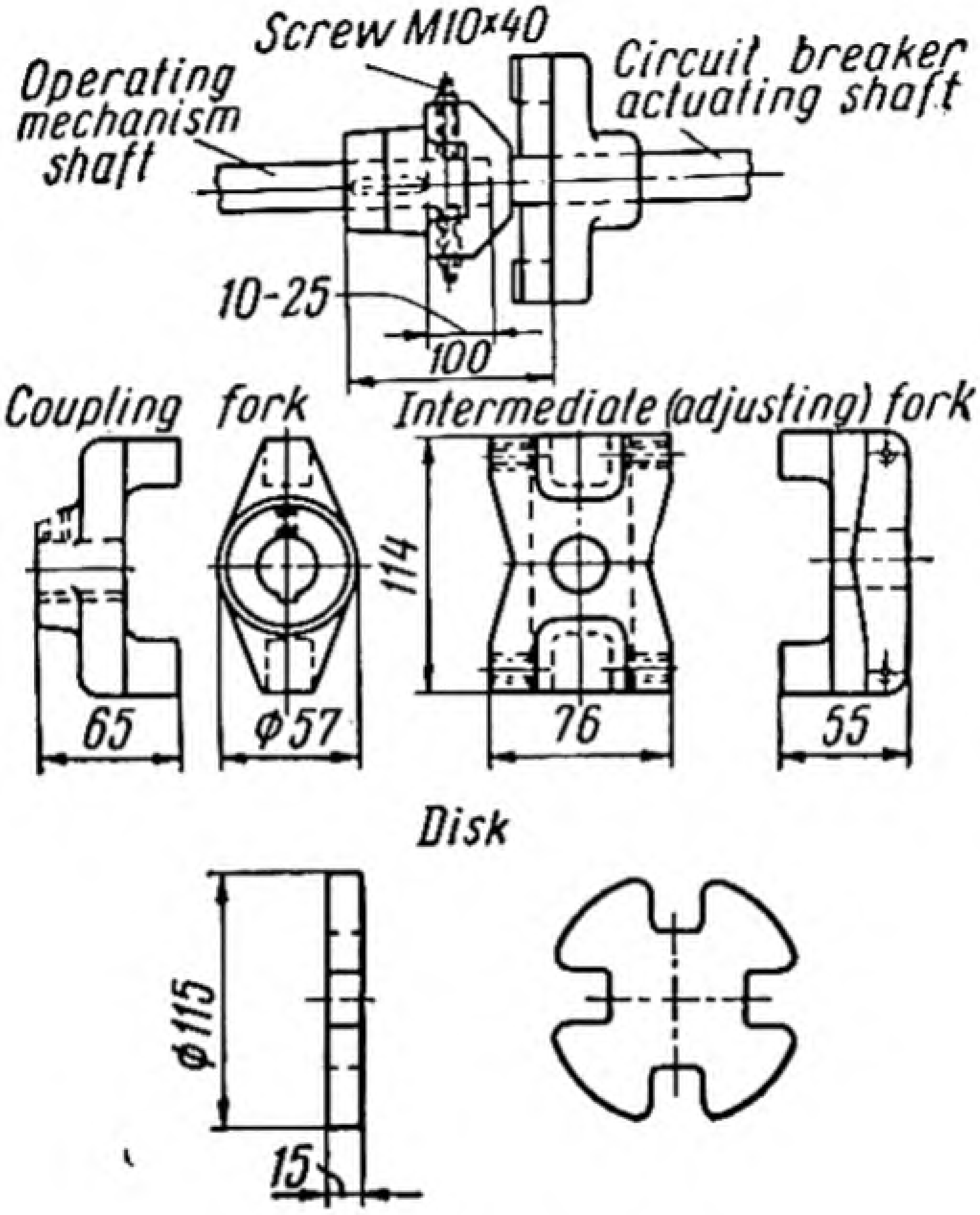


Fig. 174. Joint coupling

3. The coupling fork is fixed on the shaft, for which purpose a hole 6 mm in diameter is drilled on both, reamed with a 6 to 7 mm taper reamer, and a taper pin is driven in.

Adjustment and testing. After the operating mechanism is connected to the BM-35 circuit breaker, they are adjusted for joint operation by varying the length of tie rod *12* inside the operating mechanism cabinet (Fig. 175) or by slacking or tightening down the screws on the adjusting fork. When properly adjusted, the closed position of the operating mechanism corresponds to the fully closed position of the circuit breaker.

The small wiring from the current transformers is taken to the terminal blocks in the operating mechanism cabinet inside a short length of $1\frac{1}{4}$-inch pipe *12* (Fig. 168) fitted between the circuit breaker and the operating mechanism. One end of the pipe is screwed and nut-locked in the circuit breaker housing and the other end is secured in the operating mechanism cabinet by two nuts.

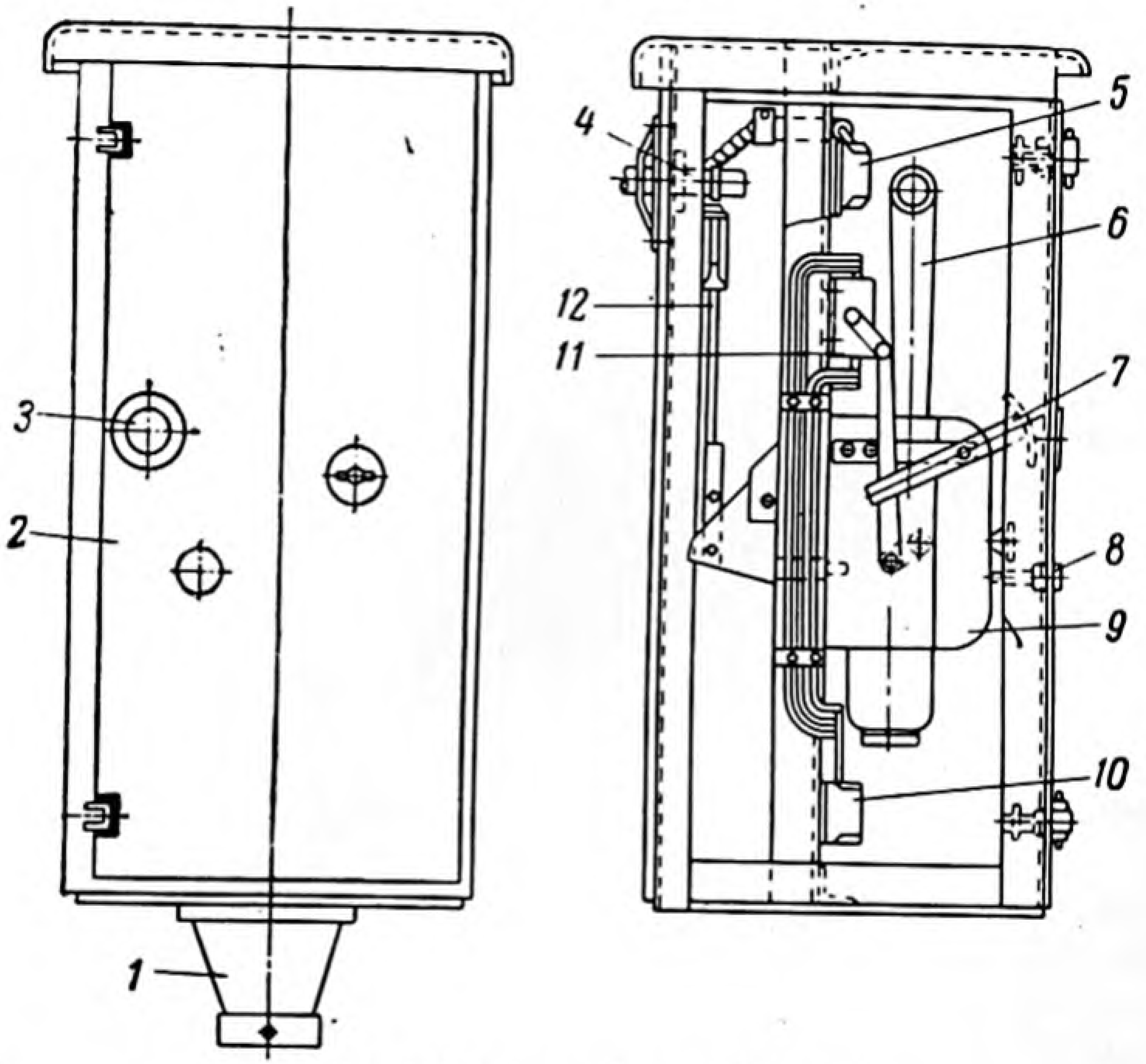


Fig. 175. ШНР operating mechanism:

1—cable box; *2*—door; *3*—position indicator window; *4*—operating mechanism shaft; *5*— terminal block for bushing current transformer connections; *6*—operating lever; *7*—position indicator; *8*—manual trip device; *9*—ПРБА manual operating mechanism; *10*—control and signalling circuit terminal block; *11*—КСА auxiliary switch; *12*—tie rod

ВМД-35 breakers arrive at the site with their operating mechanisms attached (see Fig. 169). Therefore, their installation is immediately followed by their checking and operation tests.

The testing procedure is, in the main, identical for both types. Above all, a circuit breaker is tested for positive action. If the breaker mechanism is found to seize in the closed position, the stop screw *3* on the middle-phase top plate of the mechanism (Fig. 176) must be unscrewed and the breaker closed manually, with the operat-

ing mechanism temporarily disconnected. The breaker, however, should be closed only just past the dead-centre position where it will not open if the force applied to the coupling fork is removed. After this, the stop screw should be driven in again until the circuit breaker opens. The stop screw is then given a turn or a turn and a half more and locked.

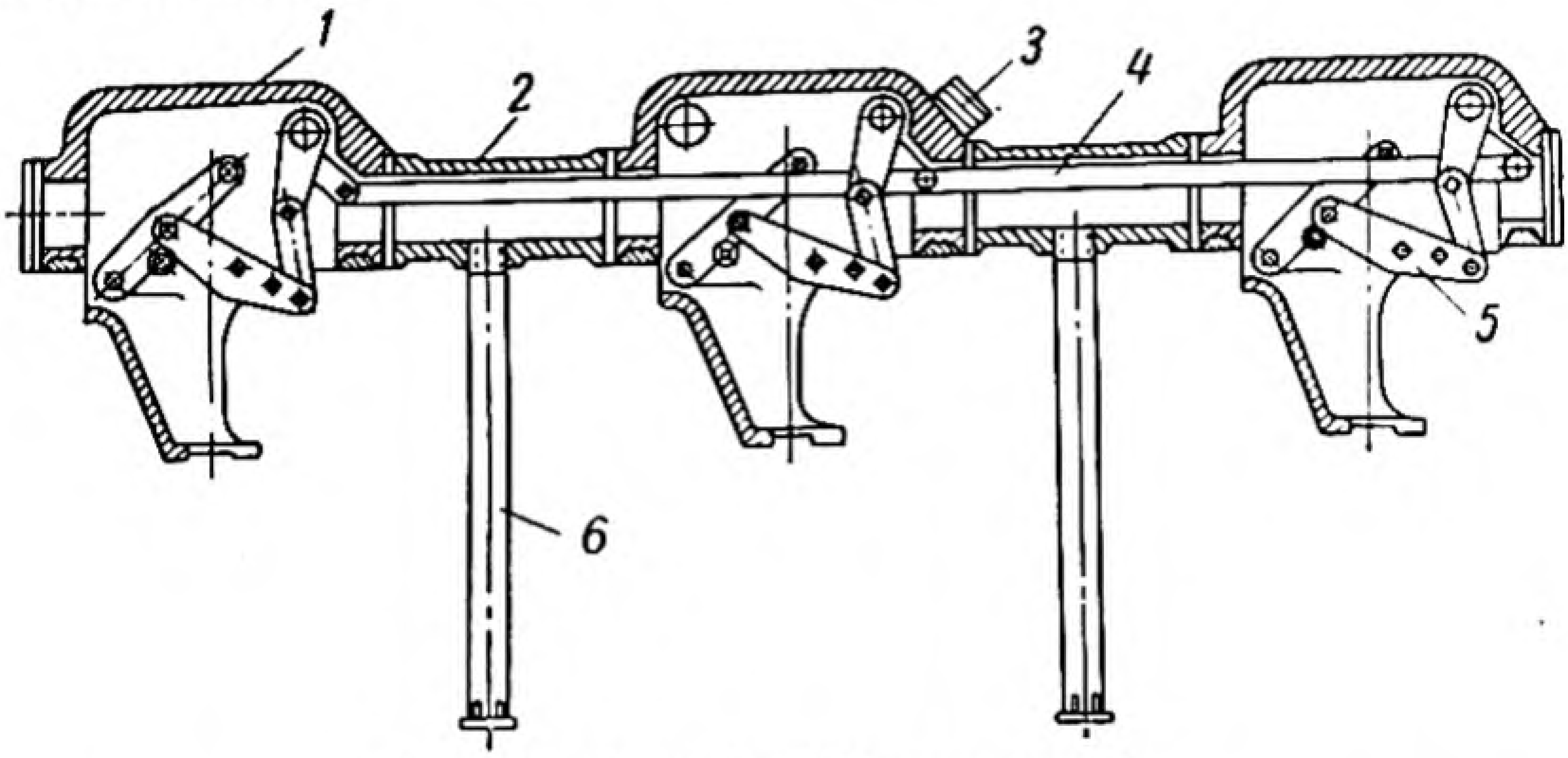


Fig. 176. Actuating-linkage cover set:
1—cover; *2*—sleeve; *3*—stop screw; *4*—horizontal linkage bars; *5*—actuating linkage member; *6*—gas vent tube with relief valve

The contacts are checked to see that they close simultaneously by means of the hook-up shown in Fig. 177. If they do so, the lamps will go on simultaneously. The tolerance is 4 mm. In other words, if the contacts of any one phase meet (the lamps in this phase light up), the blade contact of any other phase may be within 4 mm of its mating contact. The contacts are adjusted for simultaneous closure by adjusting the position of the blades along the lift rods (Fig. 178), for which purpose their nuts *5* must be loosened. When necessary, the arc control chamber *14* may be slightly shifted on the lower part of the current-conducting rod *9* in the terminal bushing *11* (see Fig. 170).

Another point to attain in adjusting the contacts for simultaneous closure is that a blade should enter its mating contacts 10 to 14 mm after they first touch each other for the springs to develop the necessary contact pressure.

Normal full travel of moving contact should be 235^{+2}_{-10} mm.

After contact adjustment, the arc barriers *3*, removed during the adjustment, are reattached.

The contacts of the auxiliary switch are adjusted by varying the length of the link rods and of the arm which fastens the links to the operating-mechanism shaft.

Filling with oil and putting into service. The circuit breakers under discussion come from the manufacturer empty of oil. Before they may be filled with oil, their tanks should be thoroughly cleaned and wiped, and their drain valves flushed with oil. All the internal insulating parts should be wiped with clean rags moistened with petrol. The oil gauges should be checked for correct indication.

The manufacturers recommend that the breakers should be dried out before their tanks are filled with oil. The simplest method of drying out is to

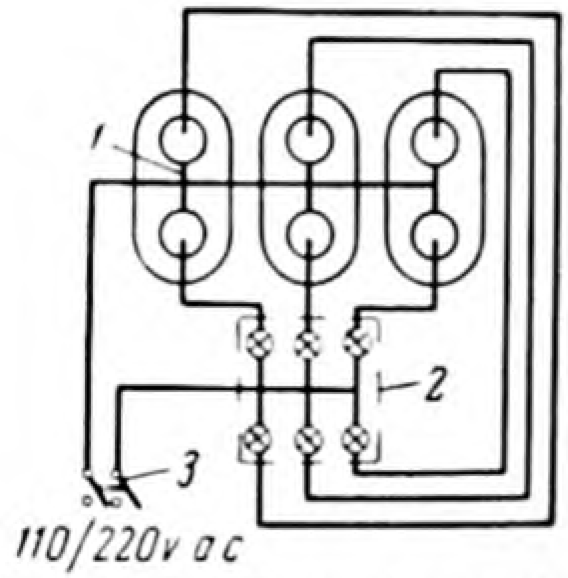


Fig. 177. Test circuit for checking breaker contacts for simultaneity of closure:

1—cross-arm; 2—lamp panel; 3—switch

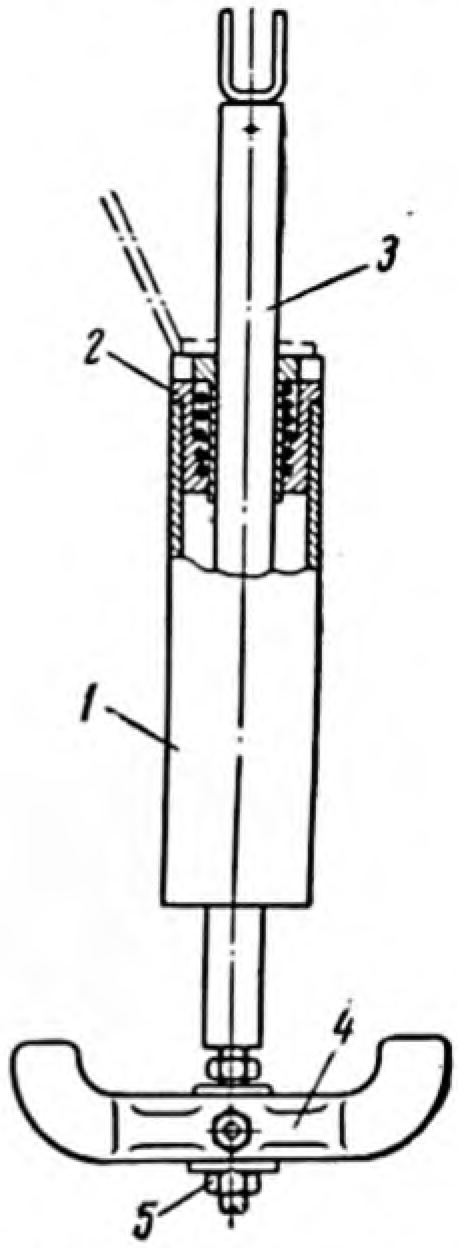


Fig. 178. Moving contact:

1—guide tube; 2—oil dash-pot; 3—lift rod; 4—cross-arm; 5—nut

hang from the contact blades electric lamps totalling 1,000 watts connected to a supply through a rheostat. The tank is slightly lowered for better ventilation. The lamps are switched on and their glow is adjusted so that the temperature at the tank walls reaches 70° C during a warm-up period of $3\frac{1}{2}$ hrs. Drying proper is carried out for 8 to 10 hours.

The filled tanks are centred and lifted in place. The centring procedure is as follows: place a straight edge across the lowered tank so that it touches the two barriers of the arc-control chamber of one phase on one side and draw marks on the breaker framework; repeat this procedure on the other side of the same phase; divide the distance between the two sets of marks made (Fig. 179) and mark off the mid-point *3*. When the tank is lifted into position, its welded seam *2* should be directly opposite the centre mark on the framework.

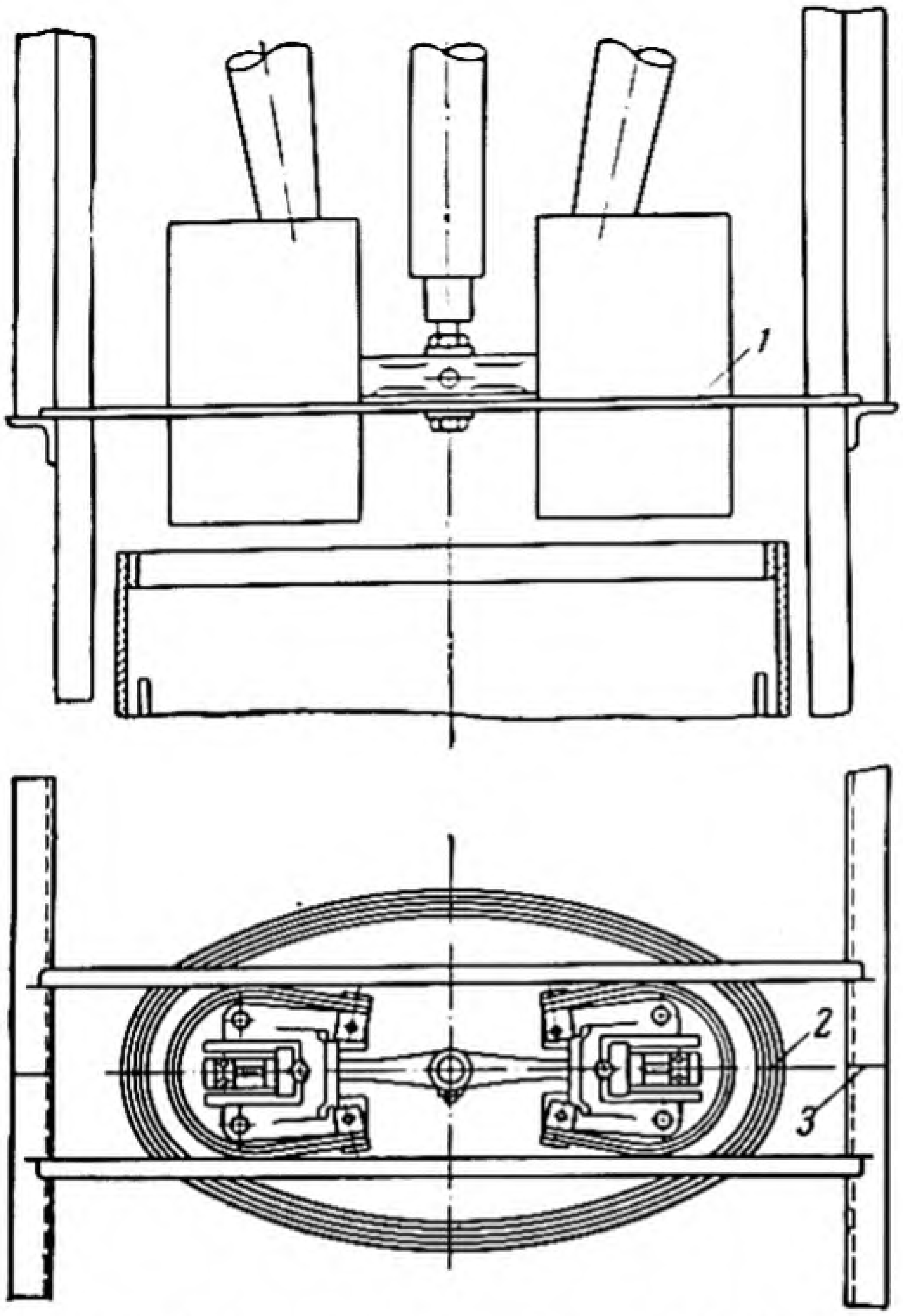


Fig. 179. Centring checking:

1—straight edge; 2—tank weld seam; 3—midpoint mark on framework

Before it is put into service a BM-35 oil circuit breaker is given as many as twenty trial closing operations in succession. The tripping should be accomplished by the automatic control devices.

In the case of a ВМД-35 breaker, it should first be closed manually and then given five closings performed by remote control at 80 per cent control voltage, five closings at rated voltage, and two or three closings at 110%.

The voltage is measured across the terminals of the operating mechanism. In trial closings, intervals of sufficient length should be maintained between operations to allow the closing-solenoid coils to cool off.

The breaker framework should be connected to the earthing system.

All the rubbing parts in the operating mechanism should be lubricated with petroleum jelly or grease, or, in locations having low ambient (sub-zero) temperatures, with nonfreezing grease.

Problem. Write up an operation sequence for the installation of a ВМД-35 outdoor oil circuit breaker to the drawing given in Fig. 169.

29. Mounting of an МКП-35 Oil Circuit Breaker

The МКП-35 oil circuit breaker is an outdoor bulk-oil apparatus. It is shipped by the manufacturer fully assembled (but empty of oil), as a three-pole unit complete with a ШПС-30 solenoid operating mechanism. The overall and installation dimensions of this breaker are given in Fig. 180; a cross section through a phase is shown in Fig. 181, and the top-plate assembly in Fig. 182.

The circuit breaker and its operating mechanism total 2,600 kg in weight (less oil) and takes 800 kg of oil. This circuit breaker may also be operated by a ШПЭ-2 mechanism.

These oil circuit breakers are shipped from the manufacturer's works locked in their closed position and crated. The control key, screw jack and signal lamp fittings are stowed in the operating mechanism cabinet.

As the operating mechanism is a heavy piece of equipment, the circuit breaker should be so lifted on the slings that the axis of the lifting hook runs between the first and second phases (Fig. 183), or the crate may turn over.

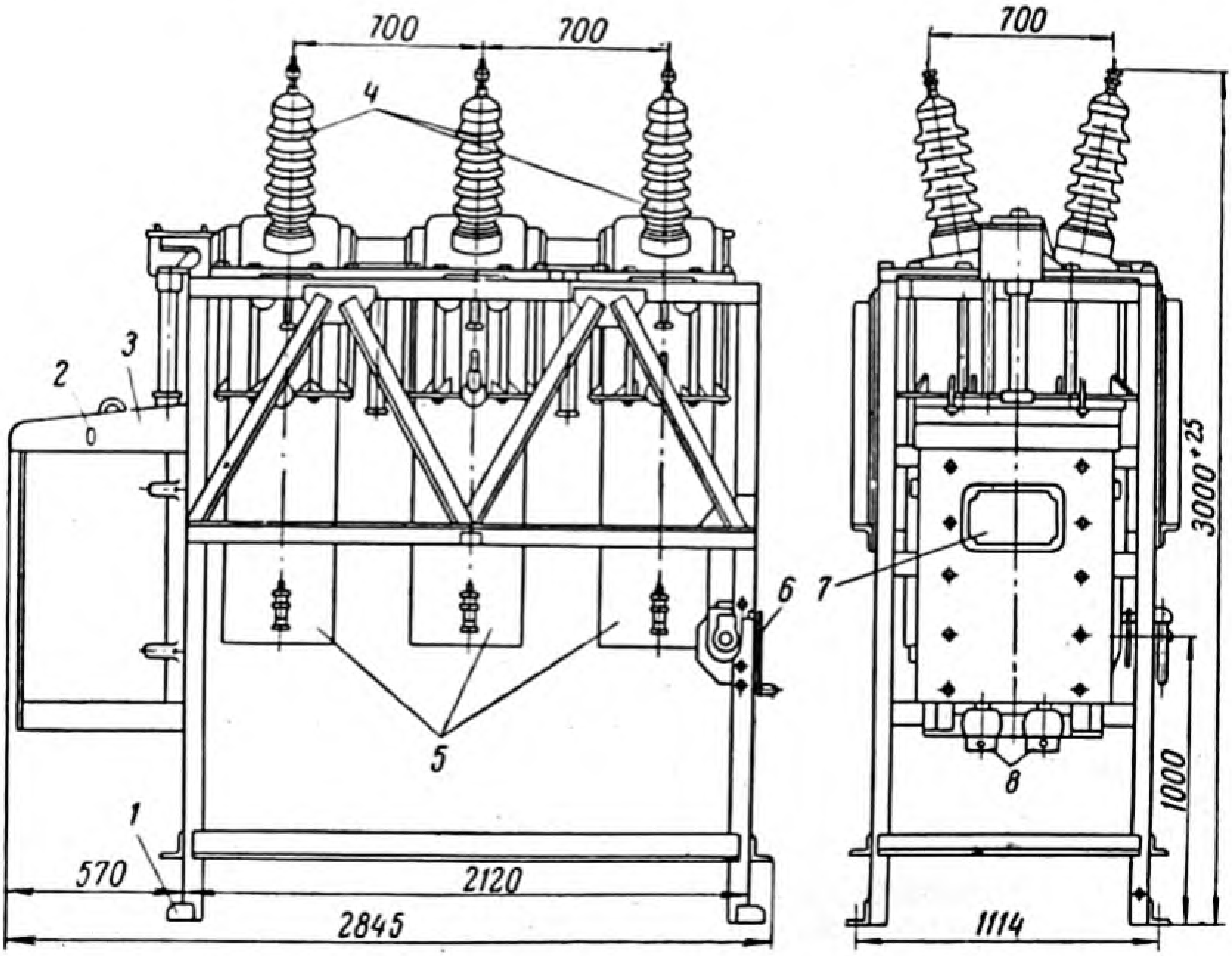


Fig. 180. General view of МКП-35 oil circuit breaker:
1—breaker framework; 2—manual trip lever; 3—ШПС-30 solenoid operating mechanism; 4—bushings; 5—tanks; 6—tank raising and lowering winch; 7—nameplate; 8—cable boxes

Take-down inspection before installation. A circuit breaker, when received, is first checked for possible breakage of its crating, unpacked, and checked for missing parts against the shipping list attached by the manufacturer. Following this, the circuit breaker is given a visual inspection for broken porcelain bushings (Fig. 184). Then the circuit breaker, for visual internal inspection, is opened, and the pole tanks are lowered with the aid of the winch *6* (see Fig. 180) mounted on the breaker framework. To lower the tanks, the wire rope is passed over the sheaves of the tank to be lowered, and slightly tautened; the eight bolts securing the tank to the circuit breaker top plate are removed; and the winch is operated to lower the tank onto wooden boards laid on the foundation slab. The other two tanks are lowered likewise.

Before the tanks can be removed for inspection, the circuit breaker should be closed manually. The tanks are taken aside and thoroughly inspected for damaged plywood insulation, defective oil drain valves, broken glass in the oil gauges, and clogged gas vents. Then the tanks and fittings are thoroughly rinsed with clean oil. To shut out dirt, the tanks should be covered with sheets of plywood during this work.

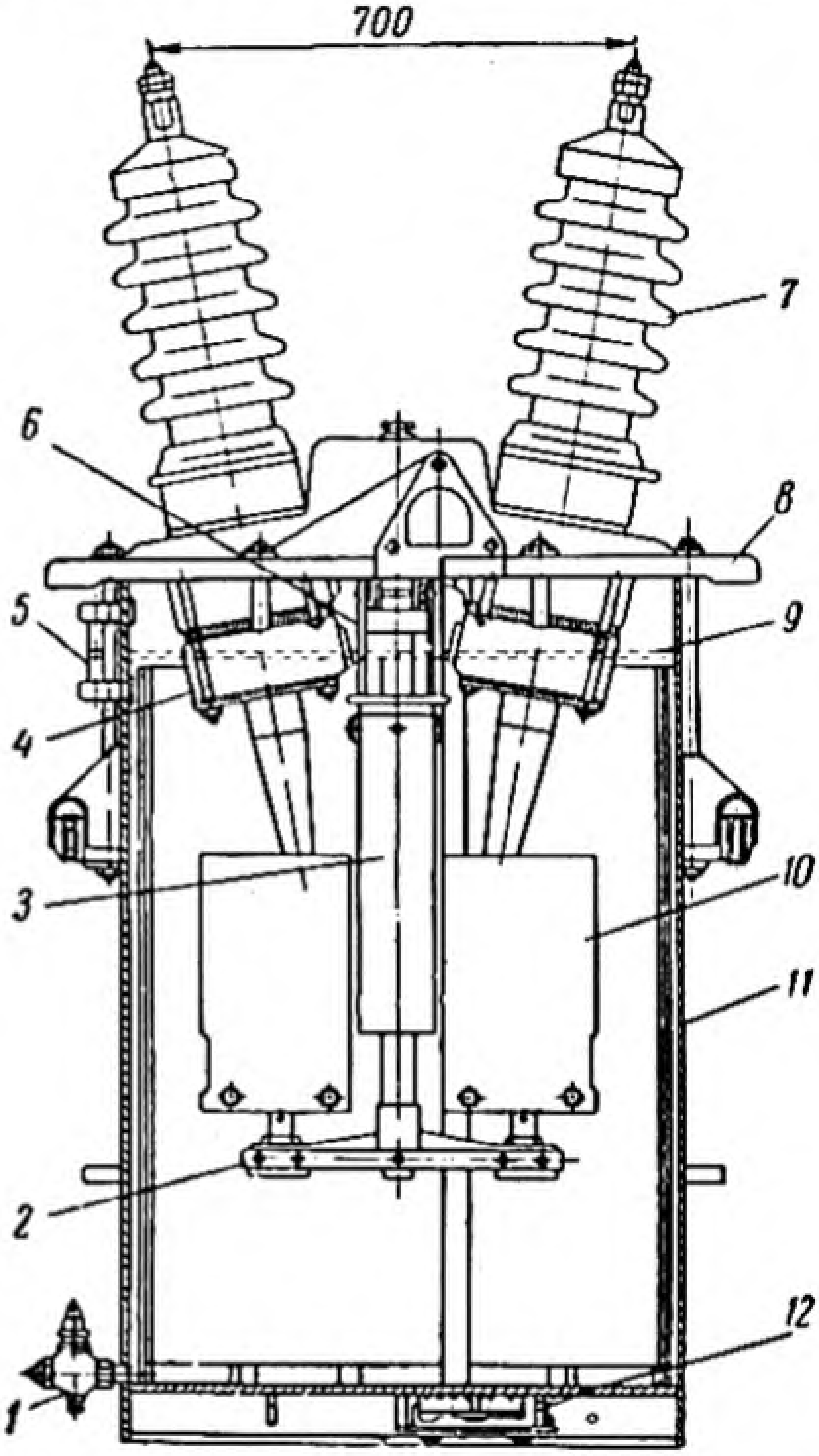


Fig. 181. Cross section through one phase of circuit breaker:

1—oil drain valve; *2*—moving contacts; *3*—guide tube; *4*—current transformer; *5*—oil-level gauge; *6*—actuating linkage; *7*—bushing; *8*—top plate; *9*—level of oil; *10*—arc-control chamber; *11*—tank; *12*—electric heater

Internal inspection should also cover the bakelised sleeves, insulating rods, bakelised barriers, actuating linkage, arc-control chambers and contact system.

The inspection of the operating mechanism should lay emphasis on the auxiliary-switch contacts, contactor and terminals.

Then all the rubbing parts of the mechanism and contacts are cleaned and lubricated with petroleum jelly. The parts of

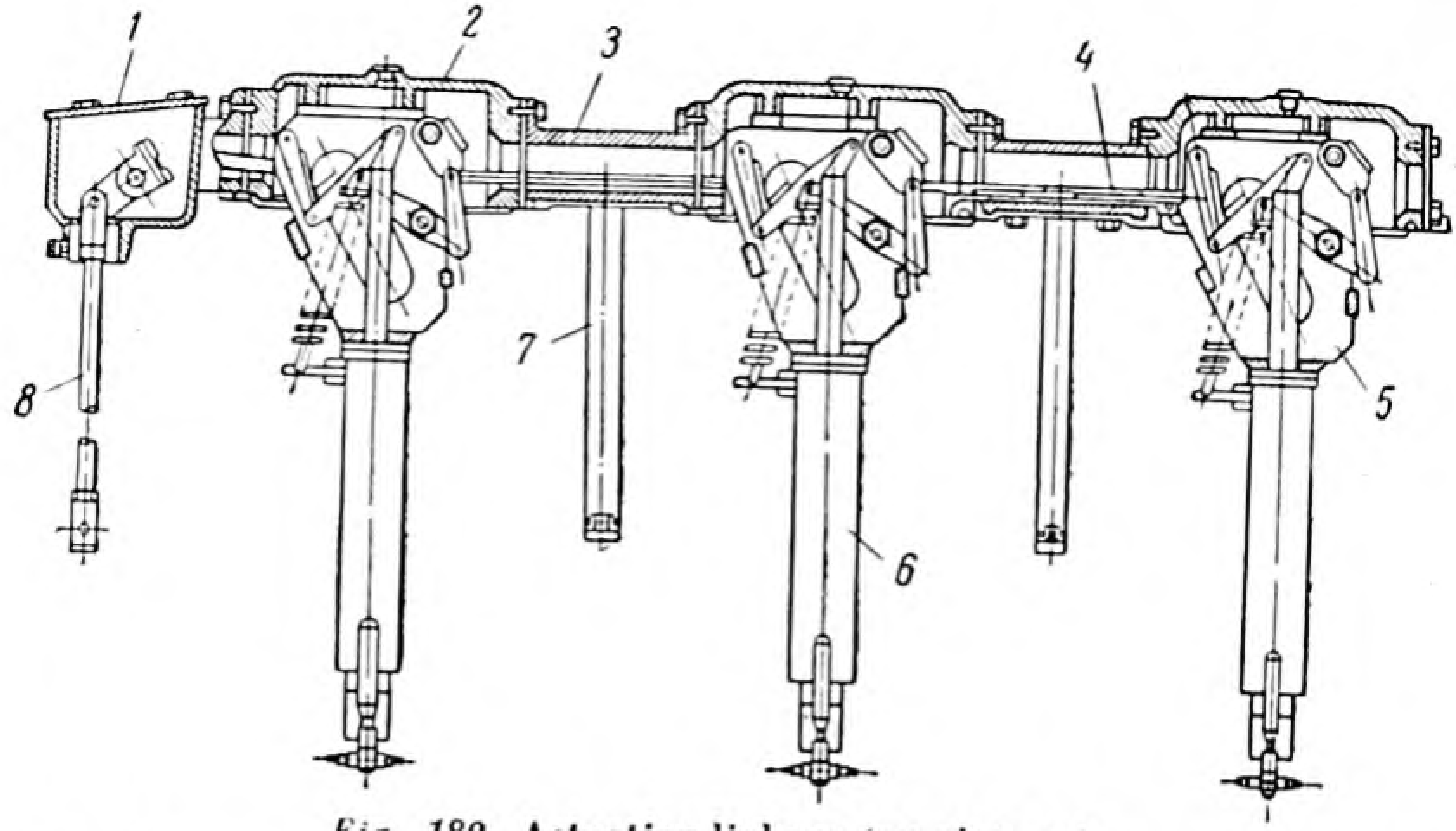


Fig. 182. **Actuating-linkage top-plate set:**

1—angle box; 2—cover unit; 3—sleeve; 4—horizontal linkage bars; 5—actuating linkage system; 6—bakelised guide tube; 7—gas vent and relief valve; 8—vertical tie rod

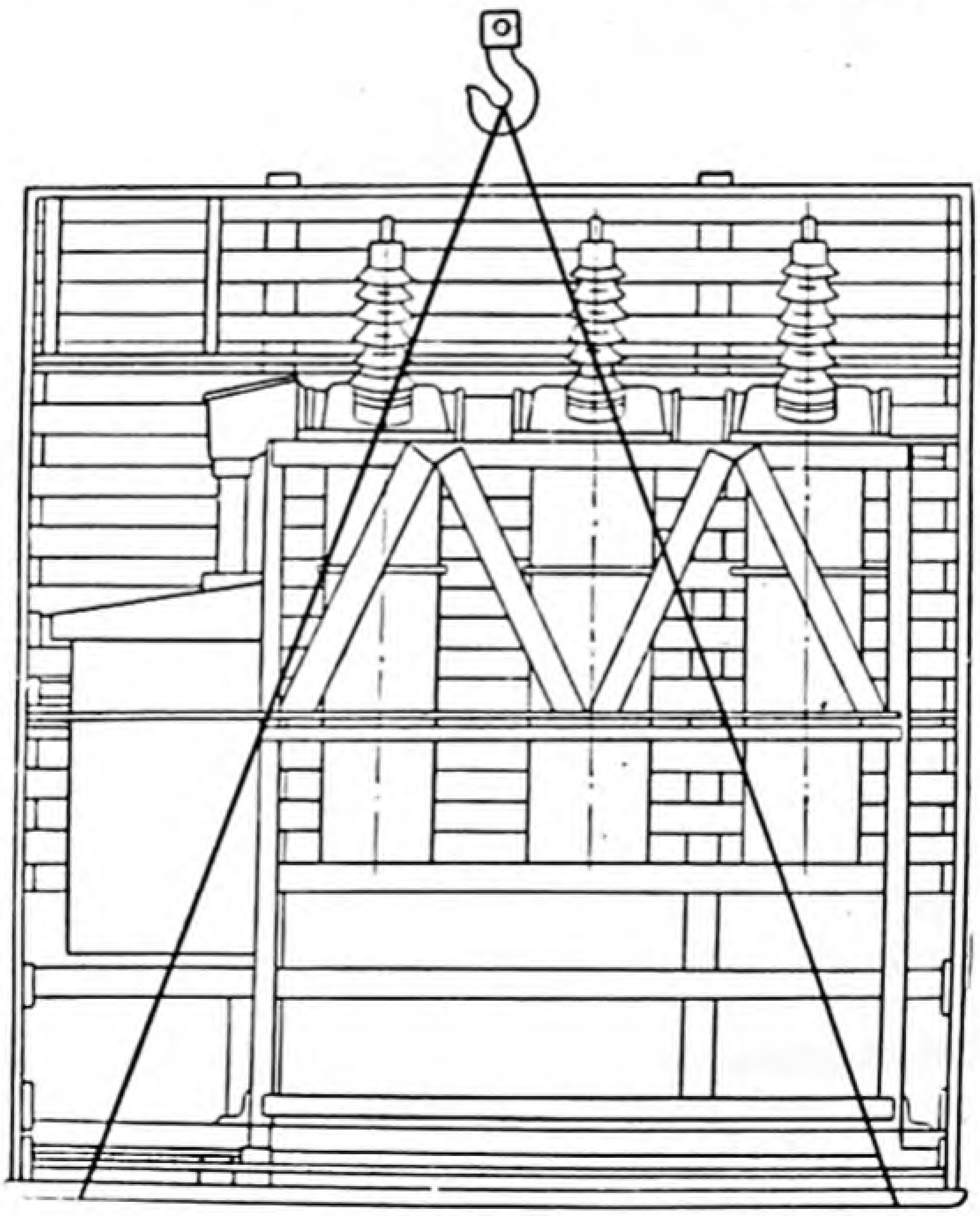


Fig 183. Position of sling ropes when lifting a circuit breaker

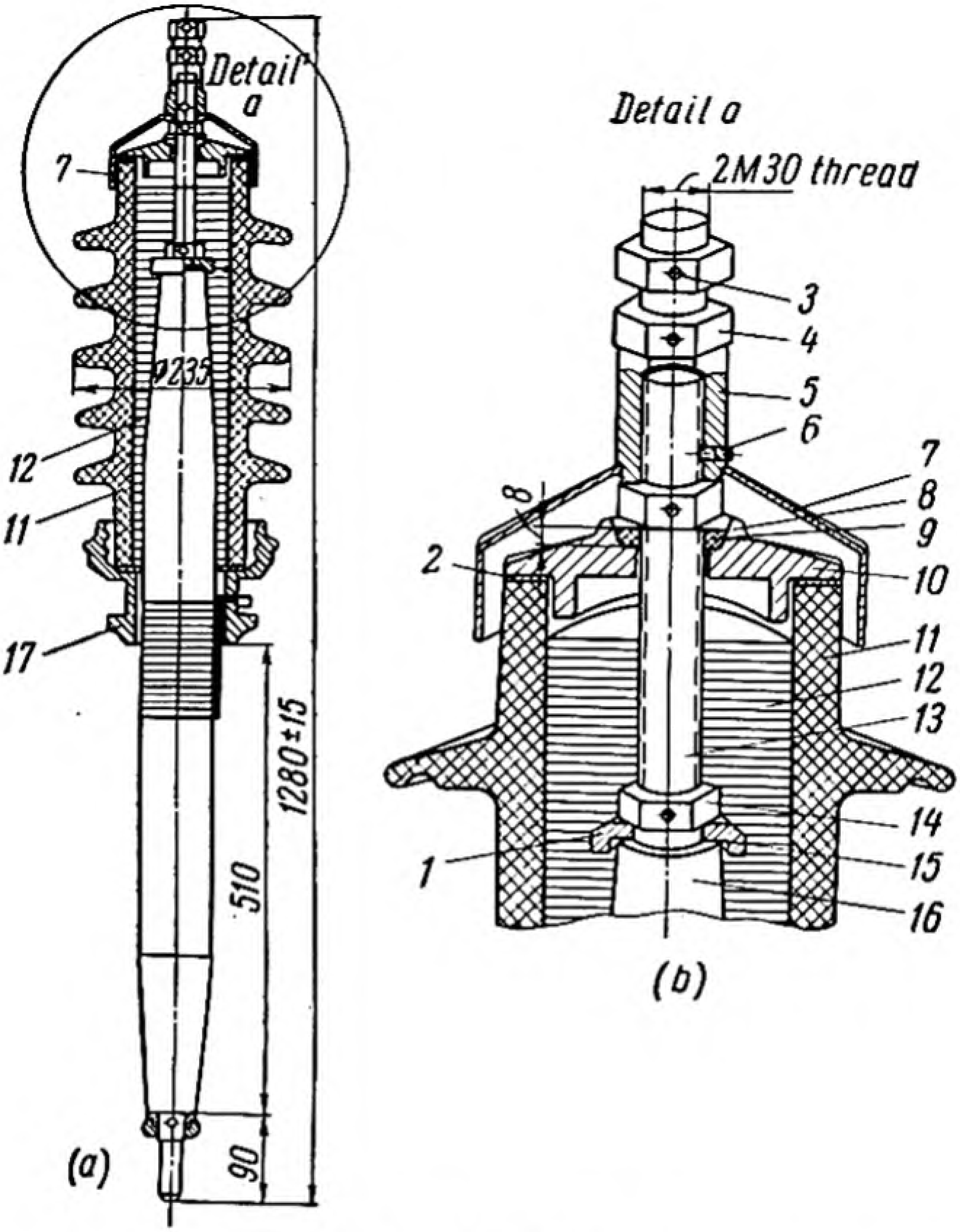


Fig. 184. Condenser bushing:

a—cross section of bushing; *b*—detail "a"; *1*—brass collar; *2*—rubber gasket; *3*—stop pin; *4*—brass nut; *5*—copper tip; *6*—stop screw sealed with tow and red lead cement; *7*—steel cap; *8*—brass washer; *9*—rubber washer; *10*—nonmagnetic, cast-iron cover plate; *11*—porcelain shell; *12*—filling compound; *13*—current-carrying rod; *14*—brass nut sealed with tow and red lead cement; *15*—pressboard gasket; *16*—condenser-paper sleeve; *17*—nonmagnetic cast-iron flange

the actuating linkage are lubricated with solidol or a similar grease.

As part of inspection the circuit breaker should be closed by means of its operating mechanism and screw jack.

When a circuit breaker is kept in storage, the manufacturer recommends that the tanks should be filled with dry transformer oil to

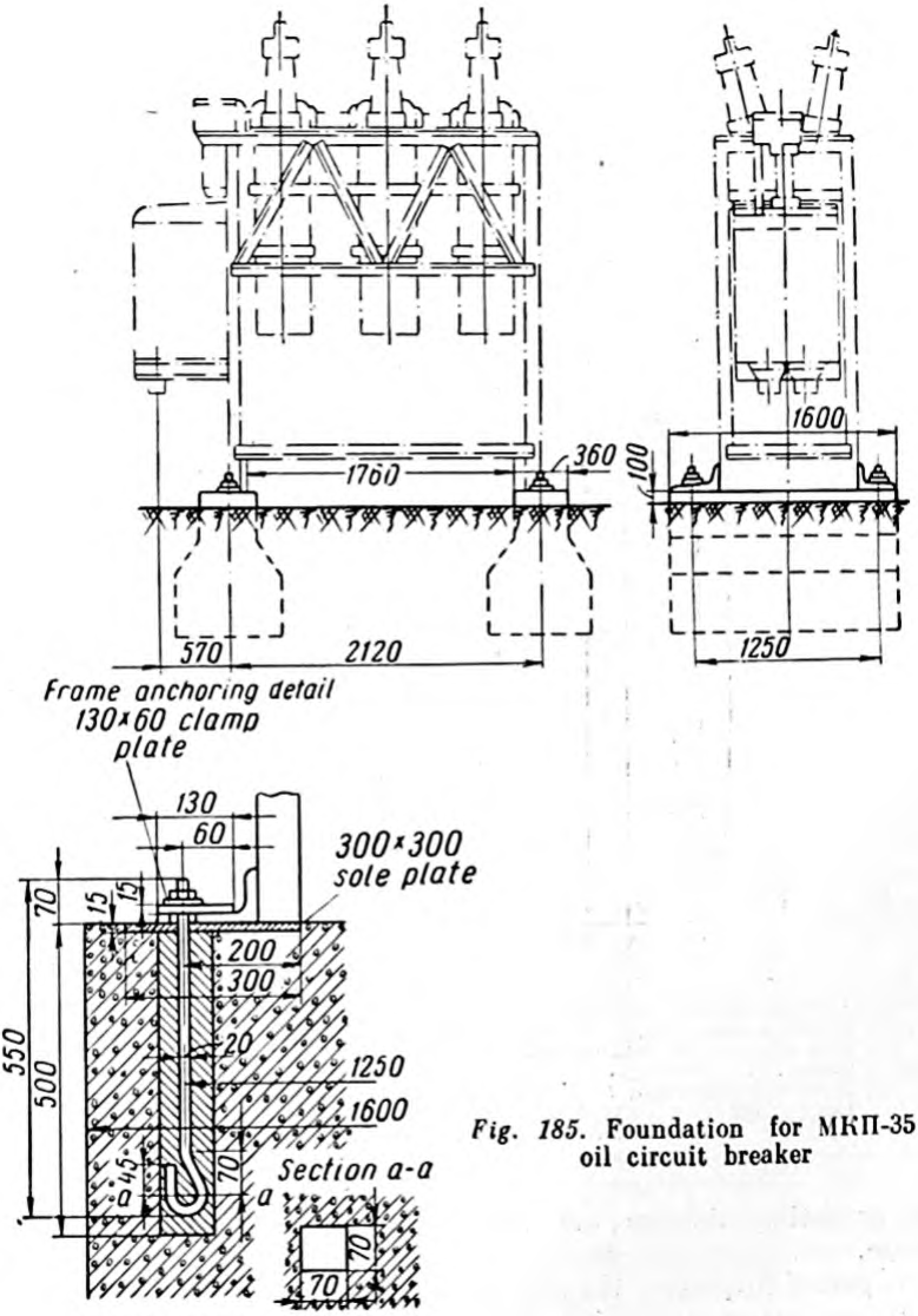


Fig. 185. Foundation for МКП-35 oil circuit breaker

avoid the ingress of moisture and deterioration of the insulating parts.

Mounting of the circuit breaker and operating mechanism. The recommended foundation for an МКП-35 oil circuit breaker is shown in Fig. 185 together with the anchor bolt layout. The circuit breaker is put on its foundation in the same manner as the ВМ-35 and ВМД-35 breakers (see Sec. 28).

Once on its foundation, the breaker is adjusted and tested in both the closed and open positions, as well as while being slowly closed and opened with the aid of the screw jack supplied with the breaker. To make operation of the screw jack easier, a one-metre length of $1\frac{1}{4}$-inch gas pipe can be slipped on the end of the jack screw lever.

Before the breaker may be closed, its arc-control chambers (Fig. 186) should be examined and cleaned. This involves removal of the barriers *2* and the housings *8* holding the packs *11* from the arc-control chambers. For this purpose the insulating bolts which secure the barriers to their lower packs are undone and the barrier proper is lowered. Then the steel bolts fastening the chamber body to the holder *6* are unscrewed, and the body lowered. The barrier is now lifted upward and slipped on the bakelised sleeve of the bushing *7* (see Fig. 181), the chamber body is removed, and the barrier can also be removed.

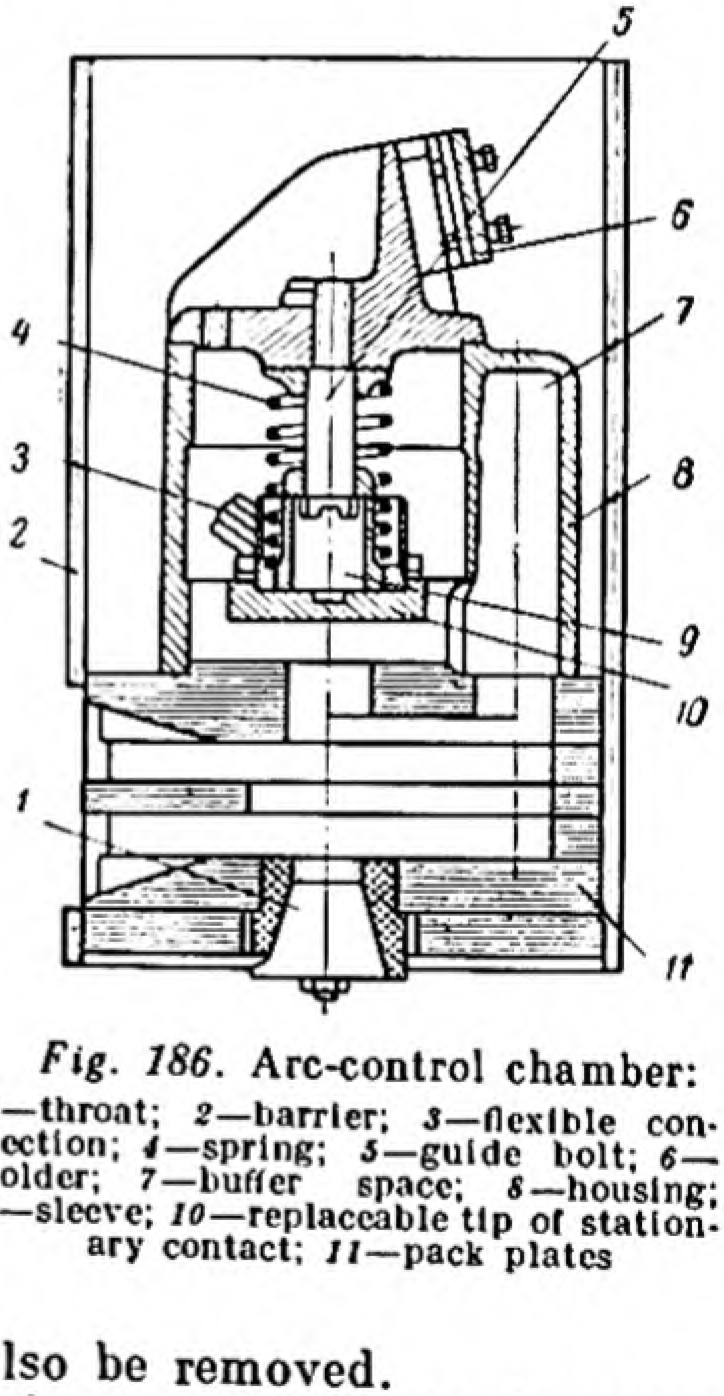


Fig. 186. Arc-control chamber:
1—throat; *2*—barrier; *3*—flexible connection; *4*—spring; *5*—guide bolt; *6*—holder; *7*—buffer space; *8*—housing; *9*—sleeve; *10*—replaceable tip of stationary contact; *11*—pack plates

Next the stop screw is backed off in the replaceable tip *10* of the stationary contact (Fig. 186) and the tip itself is unscrewed to obtain access to the guide bolt *5* in the brass collar *9* and to the bolts which secure the flexible conductors *3*.

The guide bolt should be positioned so that the faces on its head are arranged opposite the holes in the collar wall.

The bolts fastening the flexible leads should be checked to see that their ends do not enter the ring recess of the collar receiving the spring.

After the inspection, all the contact surfaces should be thoroughly cleaned, the contact tip screwed tightly back in place and locked

with its stop screw, and the holder *6* checked for reliable connection to the bushing rod.

The circuit breaker is now closed with the screw jack, taking care that the cross-arm contact rods enter the arc-control chambers along their centre lines. In its closed position, the circuit breaker should be held latched by the operating mechanism.

When the circuit breaker is closed, the pawl of the jack is swung through 180° and the jack screw is lowered, and the actuating linkage of each pole is then checked for proper positioning (Fig. 188) with a template (Fig. 187). The middle pivot may stop within 2 to 3 mm of the template (Fig. 189).

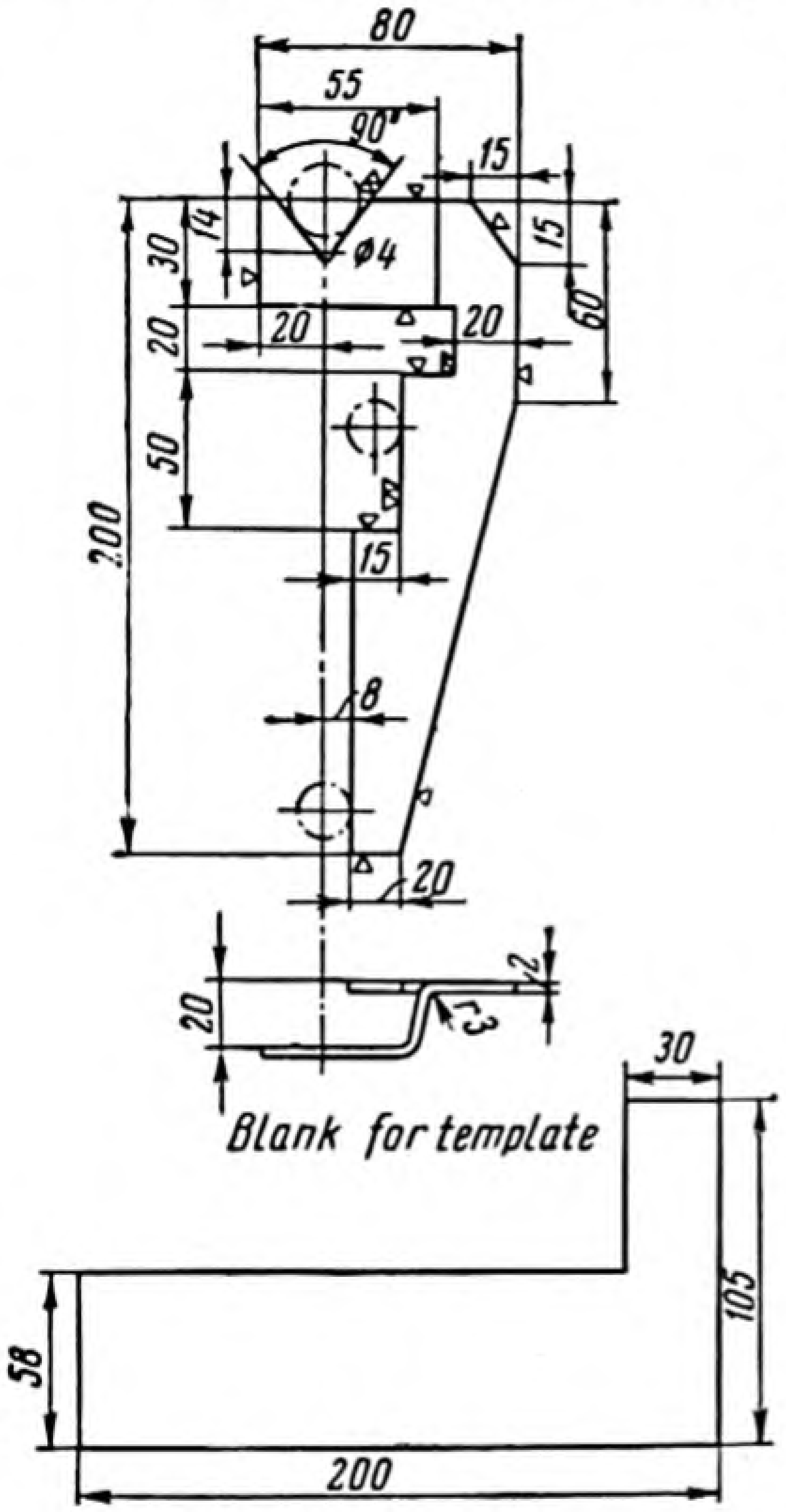


Fig. 187. Template for checking closed position of actuating linkage

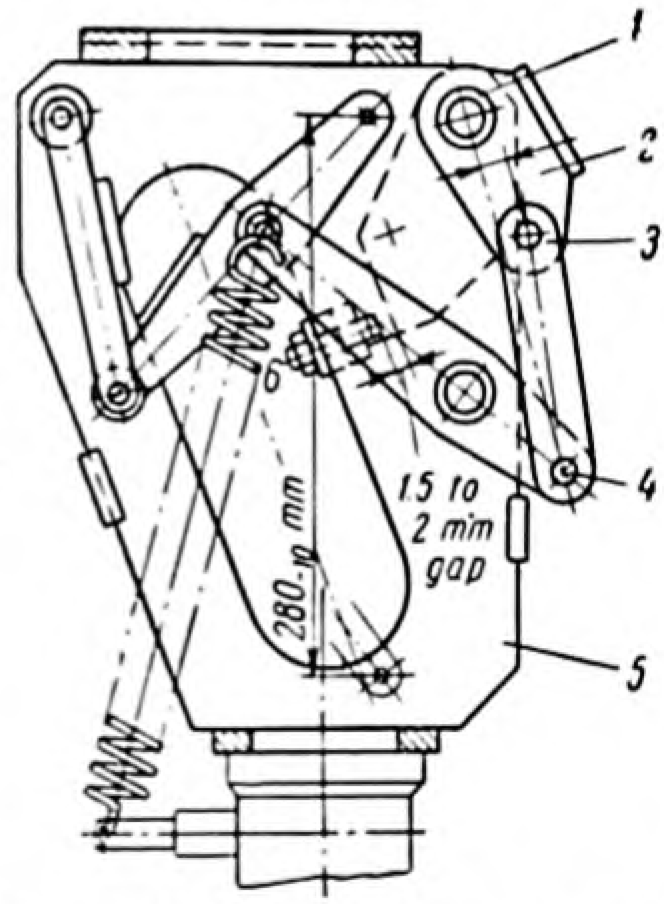


Fig. 188. Circuit breaker actuating linkage:

1, 3, 4—shafts subject to position check; *2*—drive lever; *5*—frame of actuating mechanism; *6*—travel-limit screw

If the template check shows that the relative position of the links is other than required, the horizontal tie rods *4* (see Fig. 182) should be either shortened or lengthened by screwing their end fittings in or out.

When the deviation is the same for the linkage of all three phases, they may be adjusted by means of the vertical tie rod *8* linked with the operating mechanism alone.

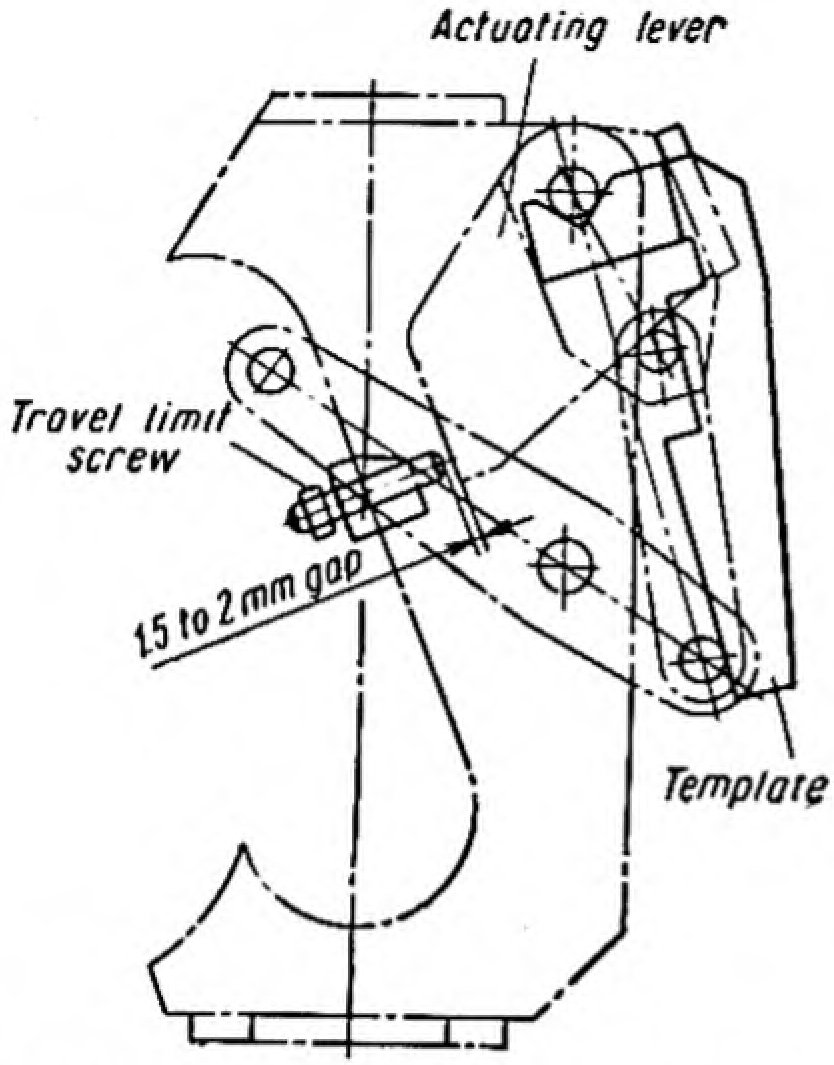


Fig. 189 Closed position of circuit breaker being checked by means of template

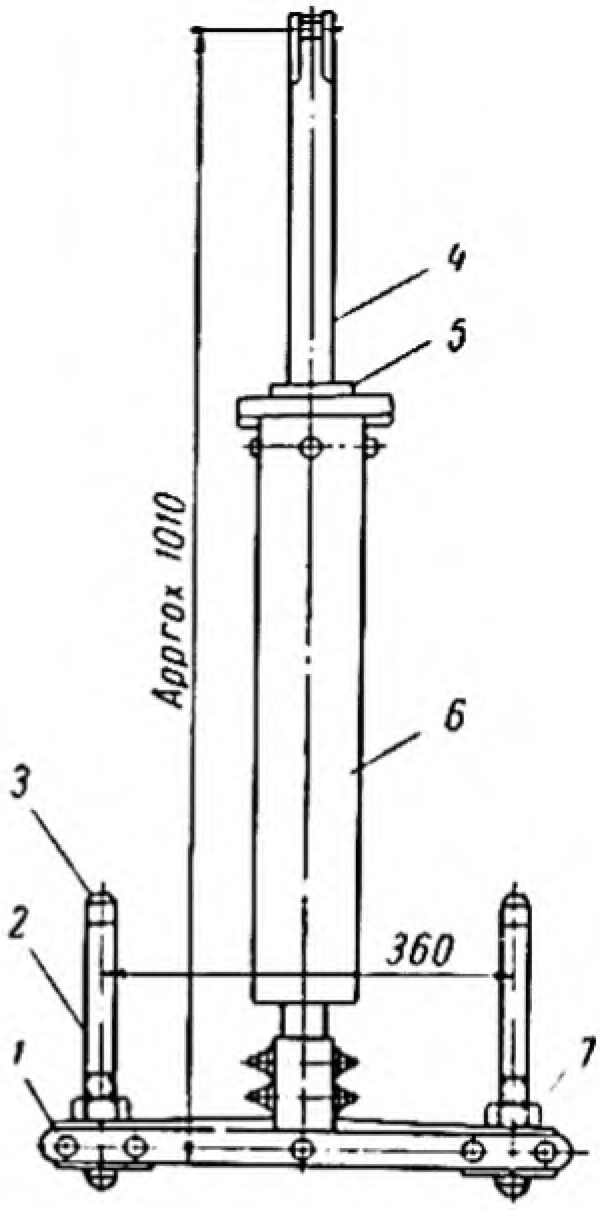


Fig. 190. Lift rod and cross-arm with the moving contacts:

1—cross-arm; 2—contact rod; 3—contact tip; 4—lift rod; 5—oil dashpot; 6—guide tube; 7—lock nut

The links in the actuating mechanisms are in their proper position when the gap between the actuating lever and the limit screw is 1.5 to 2 mm (Fig. 189).

The limit screw serves to prevent the levers from shooting past the dead-centre position, which may occur due to the inertia of the breaker mechanism when it is being closed electrically. Next the contacts are checked to determine that they close simultaneously and have sufficient travel inside the fixed contacts. Simultaneous closure of the contacts is checked with lamps connected in series with each set of contacts. The test circuit is the same as for BM-35 and ВМД-35 breakers (see Fig. 177). The contacts in the various phases must make simultaneously within 4 mm of their travel.

In other words, when the contacts in any one phase just make (the lamp lights up), the contacts in the other two phases may stop within no more than 4 mm of their make positions.

The necessary adjustment can be made by screwing the cross-arm contact rods *2* either in or out (Fig. 190).

The travel inside the fixed contacts should be within 16 ± 1 mm, while full cross-arm travel must be 280 mm.

The reassembly of the breaker is the reverse of its disassembly. In putting together the arc-control chambers, care must be taken that the cross-arm contact rods are free to enter the throats of the stacks.

If any one of them rubs, the tilt of the terminal bushing must be changed accordingly.

In conclusion, the small wiring running to the operating mechanism cabinet is connected to the current transformer terminals so as to obtain the required turns ratios.

Filling of the circuit breaker with oil and putting into operation. The rules for filling the circuit breaker with oil are as follows. First, all insulating parts should be wiped clean with a petrol-moistened rag; the bottom of the tank and the drain valves flushed with oil, and the oil gauge checked for correct indication.

Before a circuit breaker is put into service, it must be tested for joint operation with its operating mechanism. The first several trial closings are carried out at a reduced control voltage (not over 180 v); then the voltage is raised to the rated 220 v; and, finally, the breaker is tested at an increased voltage (242 v).

As many as five closures are made at the reduced and rated voltages, and two or three at the increased voltage.

All the rubbing parts in the operating mechanism must be lubricated with petroleum jelly or grease.

The breaker framework must be connected to the earthing system by steel strip not less than 40×4 mm in cross section.

Problem. Answer the following questions in writing:

1. What is the sequence of operations for mounting an МКП-35 oil circuit breaker?
2. What hook-up can be used to check the breaker contacts for simultaneous closure? Draw the circuit diagram.

30. Mounting of an МГ-35 Oil Circuit Breaker

The МГ-35 is an outdoor separate-pole multitank minimum-oil circuit breaker for 35-kv service. Its installation dimensions are given in Fig. 191. Fig. 192 shows its construction.

The МГ-35 breaker weighs 926 kg without oil and the operating mechanism, and takes 120 kg of oil.

The circuit breaker is operated by a ШПС-20 solenoid mechanism, the general view and installation dimensions of which are given in Fig. 191. The mechanism weighs 160 kg.

МГ-35 circuit breakers come from the manufacturer fully assembled, adjusted and filled with oil. After it is examined for broken porcelain and missing parts, the breaker may be lifted onto its foundation by a truck crane of not less than one-ton lifting capacity. The slings should be arranged as shown in Fig. 193.

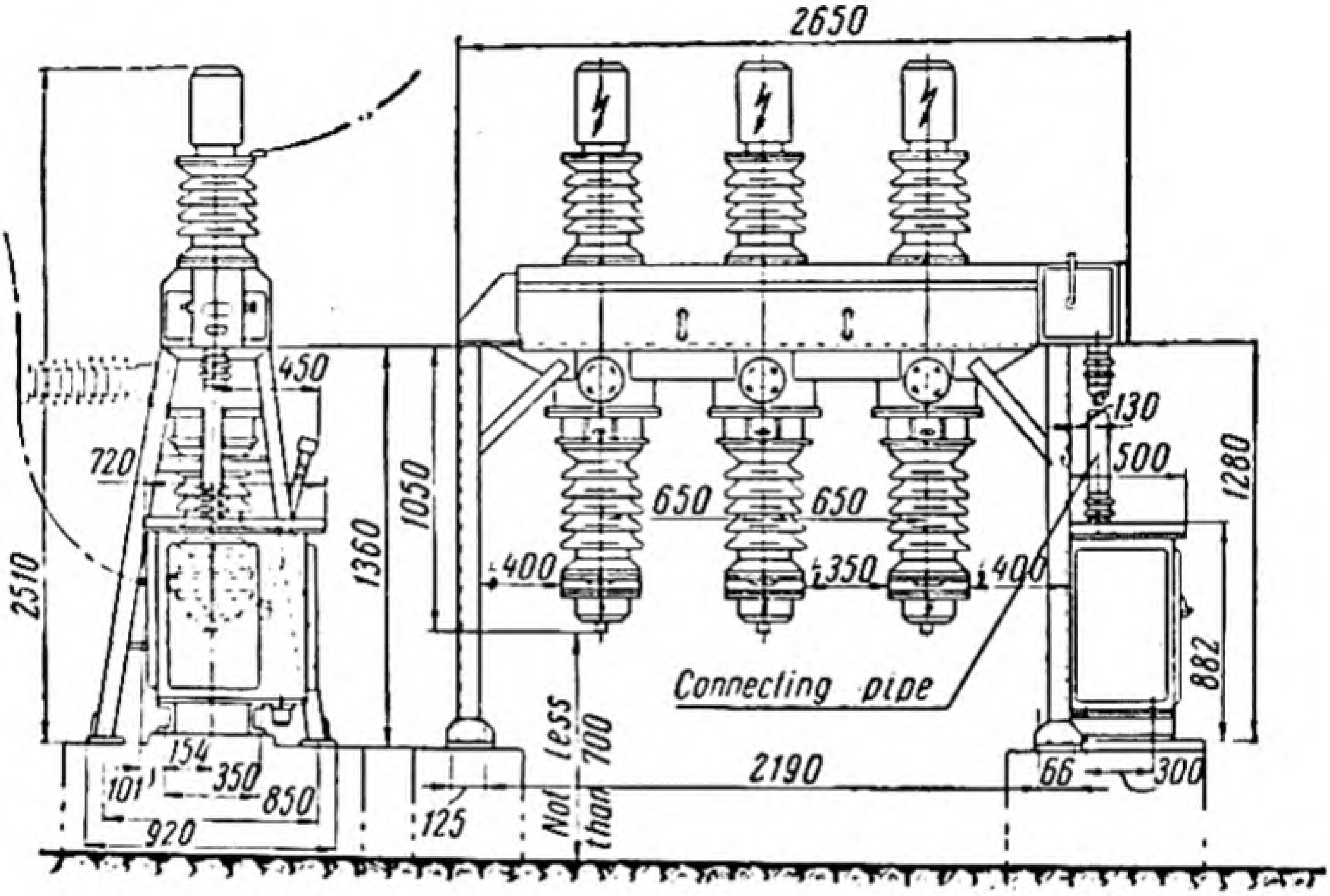


Fig. 191. General view and installation dimensions of the МГ-35 oil circuit breaker and ШПС-20 solenoid operating mechanism

Next M20 fixing bolts are inserted in the four holes in the support feet so that they enter the mating holes in the foundation. After the circuit breaker is levelled and aligned horizontally, vertically and axially, the grout is poured in around the bolts. Simultaneously the operating mechanism is mounted and secured on the head end of the breaker foundation by means of four M16 bolts (see Fig. 191).

When the circuit breaker is in place, the oil is drained, for which purpose a length of 12-mm diameter rubber tubing is attached by wire binding to the oil drain fitting *20* (see Fig. 192) in the bottom of the pots *21*. When the bush is screwed in, the oil

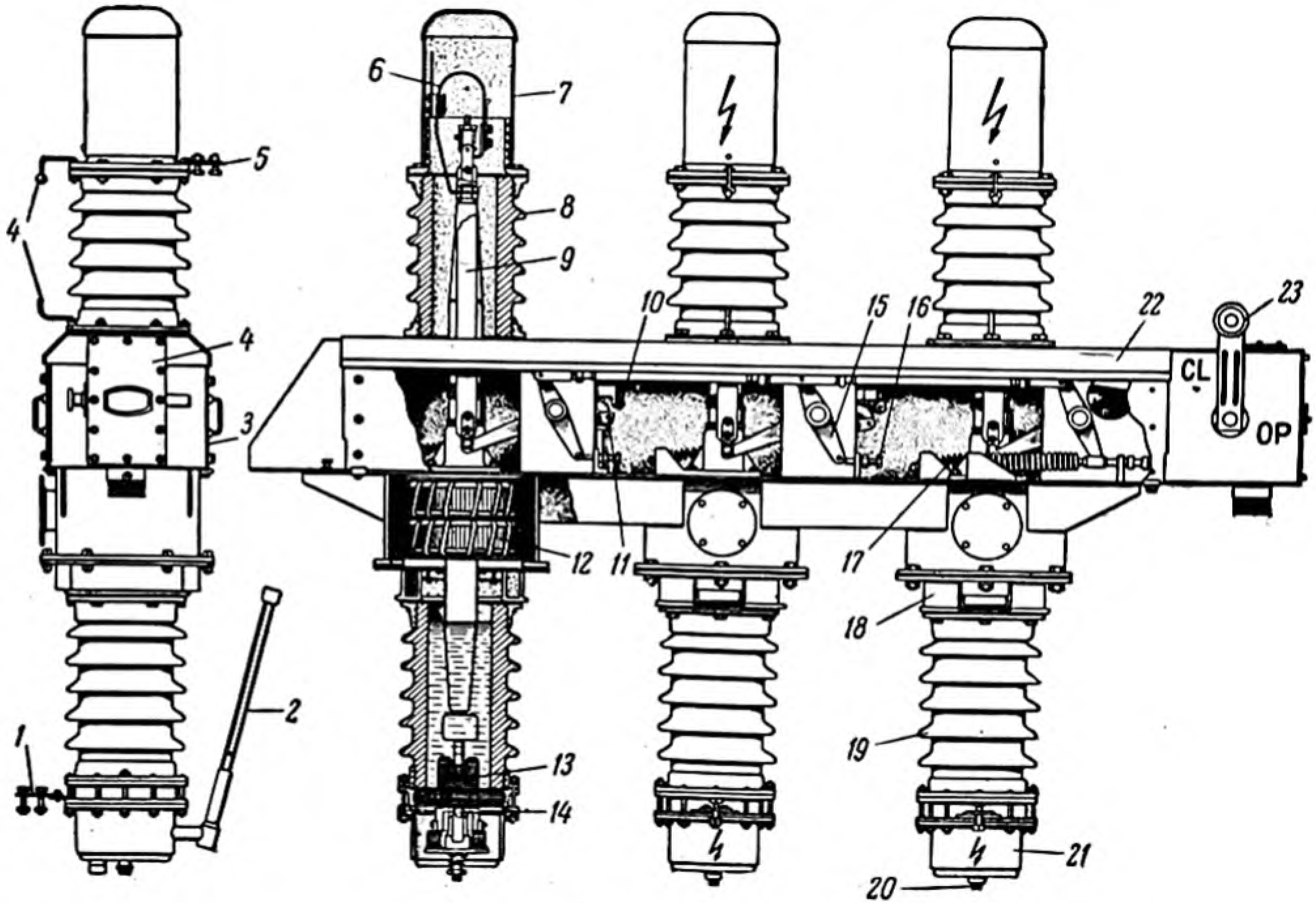


Fig. 192. General view of the МГ-35 oil circuit breaker with one phase and the actuating linkage shown in section.

1—lower terminal bar; *2*—oil level gauge; *3*—side plate; *4*—front plate; *5*—upper terminal bar; *6*—flexible lead; *7*—steel cap; *8*—upper porcelain shell; *9*—insulating tie rod; *10*—electric heater; *11*—oil dashpot; *12*—bushing current transformer; *13*— arc-control unit; *14*— replaceable tip of moving contact; *15*—double-arm lever; *16*—stop screw; *17*—opening spring; *18*—gas vent; *19*—lower porcelain shell; *20*—oil drain fitting; *21*—steel pot; *22*—frame; *23*—circuit-breaker contact-position indicator

drain fitting opens, and when it is screwed out the drain fitting is closed.

After the oil has been drained, the pots and oil gauges *2* together are removed, followed by the sides *3* and front plate *4* of the frame, and the panelling of the operating-mechanism cabinet.

Next a three-inch connection pipe is installed between the circuit breaker and operating mechanism. Its length depends on the actual distance between them (see Fig. 191).

The small wiring from the current transformers and heaters is then bunched, slipped through the connecting pipe between the circuit breaker and operating mechanism, run as required, and connected to the terminals provided in the breaker frame (Fig. 194).

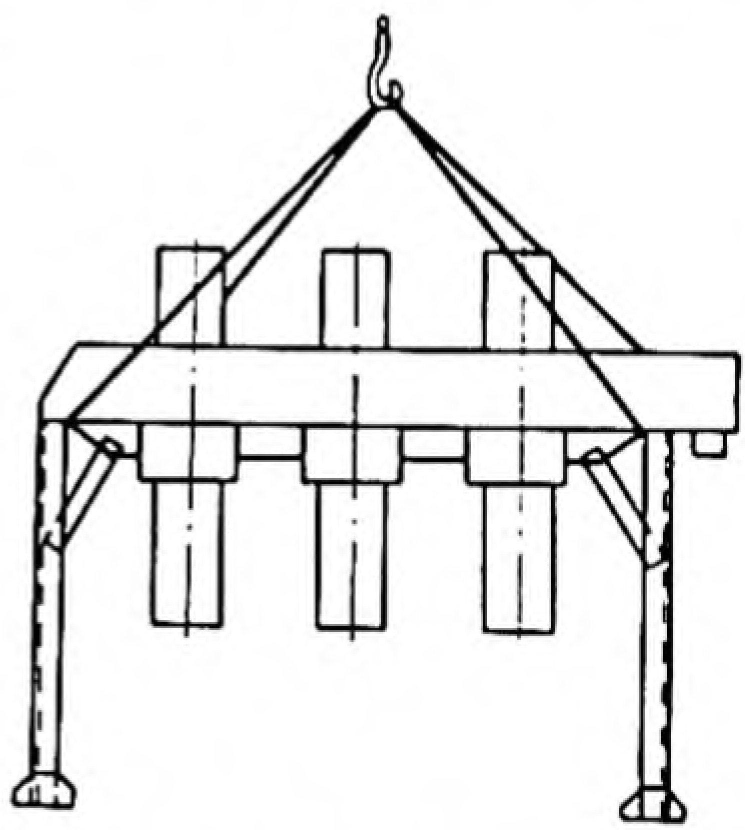


Fig. 193. Arrangement of sling ropes for lifting an МГ-35 oil circuit breaker

The following operation is to install the tie rod between the operating lever (see Fig. 195) of the breaker and the operating mechanism through the access hole in the cover of the breaker frame. The operating mechanism is closed manually, while the breaker is left open. At the same time, the levers should be checked to see whether they bear on the heads of the oil dashpots *11*.

The tie rod is made from $\frac{3}{4}$-inch gas pipe 80 mm shorter than the distance *A* in Fig. 195. This pipe is fitted with two studs, fixed by pins or welding. The upper stud is screwed into the clevis *3*, and the lower one, into the drive nut *6* of the operating mechanism.

After the circuit breaker and its operating mechanism are coupled, the closing system is checked for ease of operation. Closing is performed with the aid of a $1\frac{1}{4}$-inch gas pipe 1.5 metres long slipped on the manual closing lever of the operating mechanism.

The length of the tie rod is adjusted by means of the clevis *3* and drive nut *6* until the travel of the contact rods is anywhere between 195 and 210 mm in all three poles. To complete the adjustment, the follow of the contacts is determined as shown in Fig. 196. The procedure is as follows: the stop plate *2* is removed from the current-con-

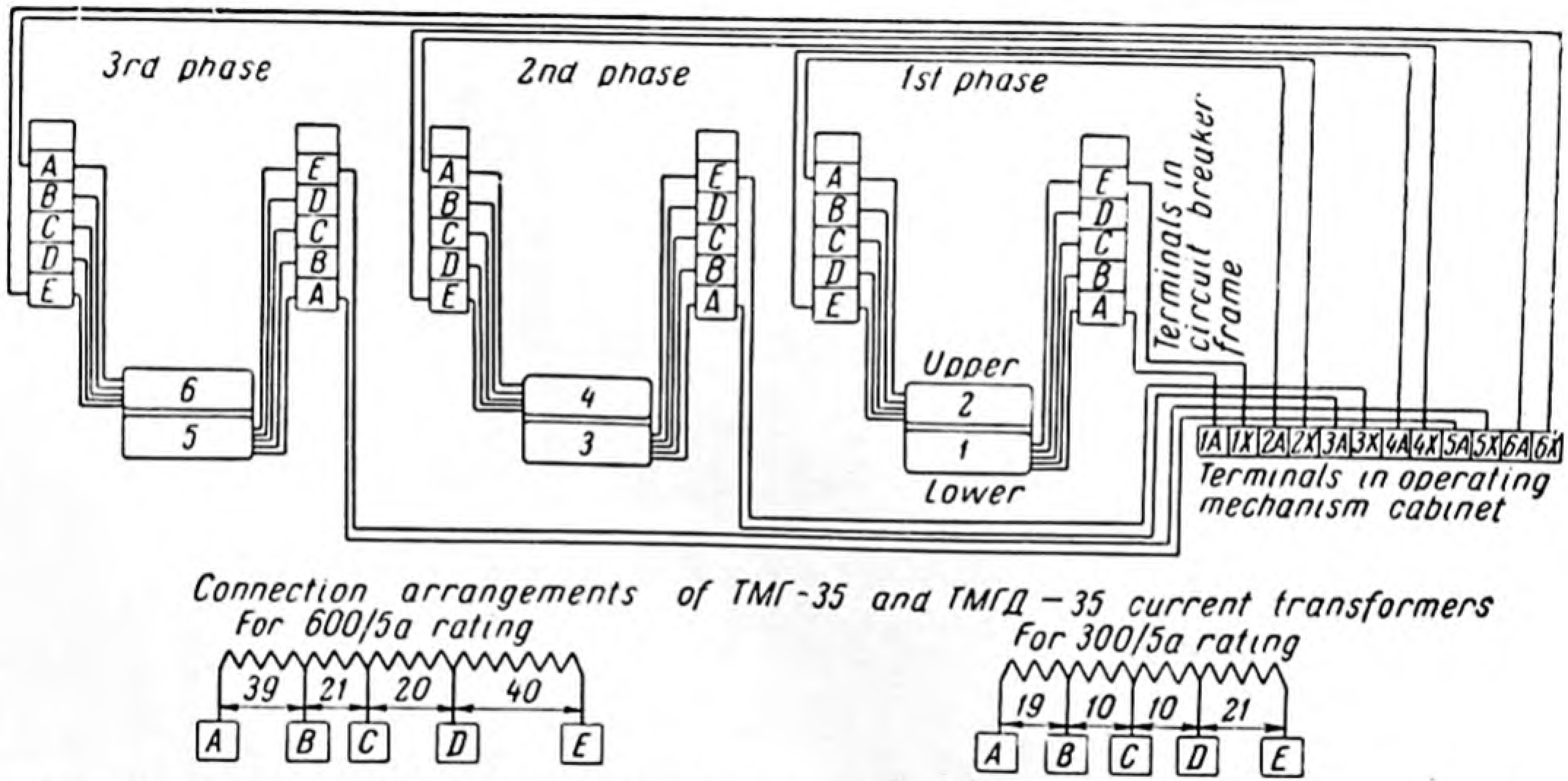


Fig. 194. Arrangement of the terminals in the operating-mechanism cabinet and circuit-breaker frame, and the current transformer connections

ducting rod *5* (Fig. 197) and the nuts are slackened; the adjusting nut *4* is screwed up or down (whichever may be the case) until the rod *5* is shifted the required distance.

After that the nut *1* is tightened snugly against the adjusting sleeve *3* and screw-locked, the limit stop *2* is re-placed, and the remaining nuts are tightened.

The point to be checked next is the gap between the end of the stop screw *16* and the back of the double-arm lever *15* (see Fig. 192), which must not exceed 1 mm when the breaker is closed.

It should also be ascertained that when the circuit breaker is closed, the breaker operating lever and the tie rod of the first pole are near the dead-centre position. Overtravel past dead-centre is a sign of abnormal condition in the circuit breaker and may result in a failure to perform an opening operation. Normally the relative position of the lever *2* and the tie rod *3* should be as shown in Fig. 198. At the same time the distance between the end of the tie rod *3* and the circuit breaker shaft should be between 5 and 10 mm.

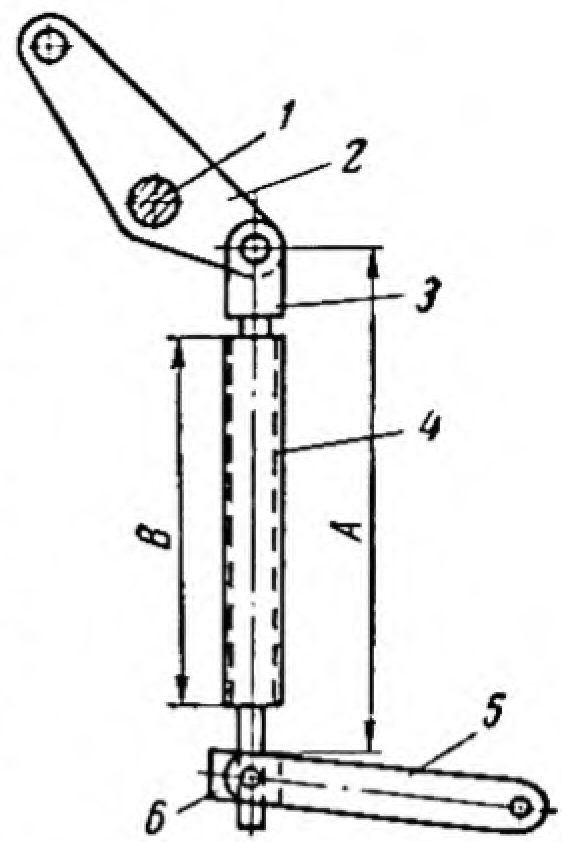


Fig. 195. Determination of tie rod length between circuit-breaker mechanism and the operating mechanism:

1— breaker actuating shaft; *2*— circuit-breaker actuating lever; *3*—clevis; *4*—tie rod ($\frac{3}{4}$-inch gas pipe); *5*—operating mechanism lever in its "closed" position; *6*—drive nut of operating mechanism

In conclusion the breaker is closed and opened several times to make sure that it functions properly from any intermediate position. If it does, the pots and their oil gauges are re-mounted and the circuit breaker filled with pure dry transformer oil level with the upper mark on the oil gauge. About 12 kg of oil are required per pole.

The oil-filled circuit breaker is then made to close and open by the operating mechanism, starting with a reduced (80 per cent) voltage, rising to the rated

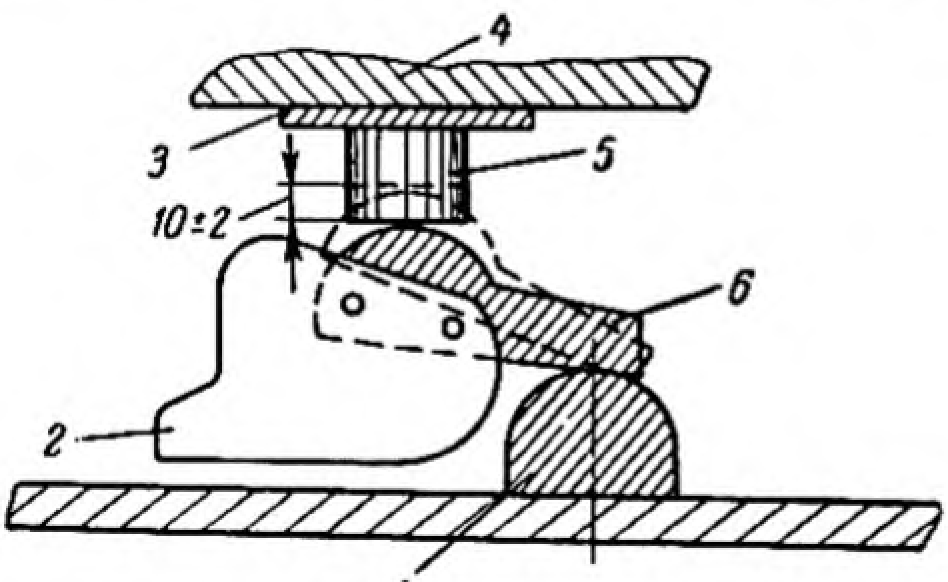


Fig. 196. Determination of in-contact follow of contacts:

1—stationary contact; *2*—intermediate contact mechanism; *3*—plate; *4*—arc-control chamber; *5*—current-conducting rod; *6*—intermediate contact

voltage, and winding up with an increased voltage (but not over 110 per cent). The trial sequence is five operations each at reduced and rated voltage, and three operations at increased voltage.

The voltage should be measured at the terminals of the operating mechanism on a closing stroke. The trial operations should be performed at intervals of 1.5 to 2 minutes, or the closing solenoid coil may be overheated.

It may so happen that the circuit breaker, after closing, fails to stay closed. The cause of this should be looked for in the auxiliary switch which may interrupt the closing circuit prematurely. This fault may be remedied by changing the angle of rotation of the contacts.

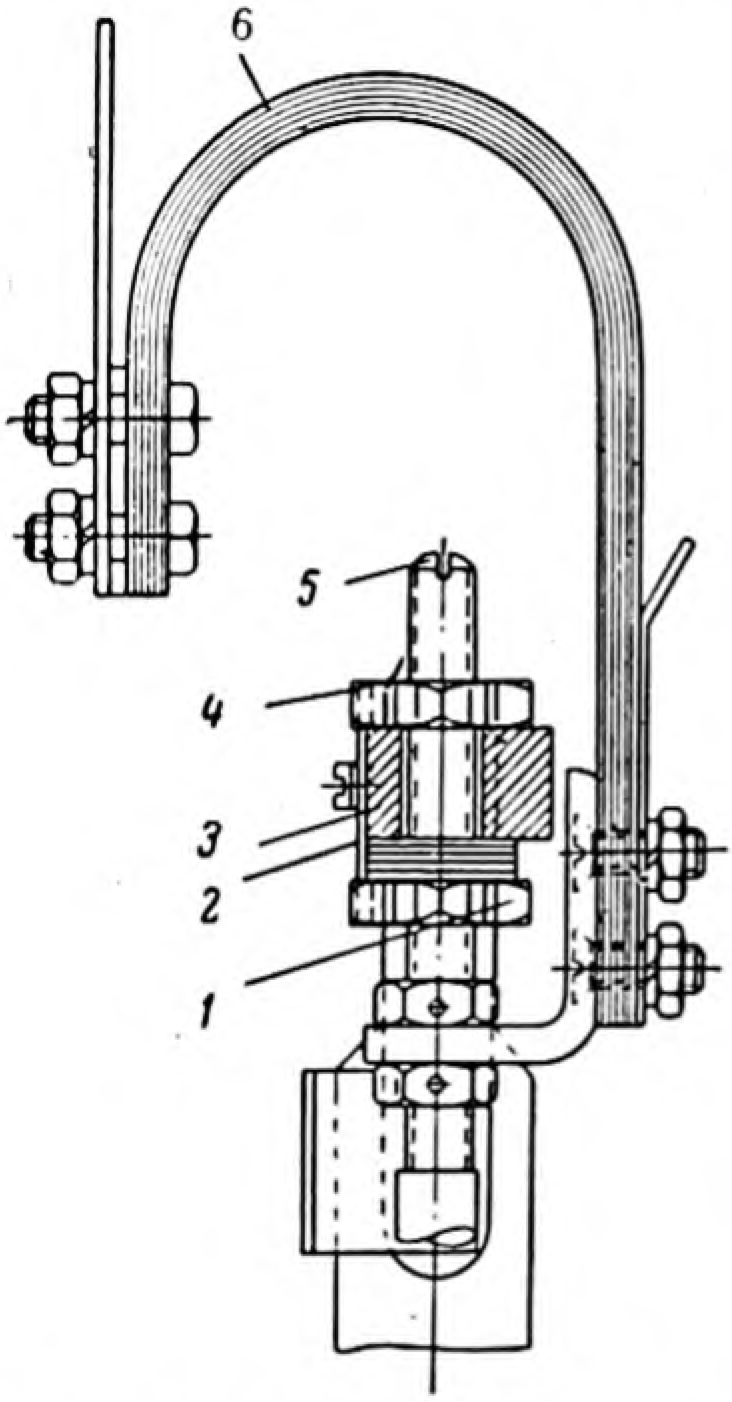


Fig. 197. Detail of the fastening parts on upper end of current-conducting rod:

1—nut; 2—stop plate; 3—adjusting sleeve; 4—nut; 5—current-conducting rod; 6—flexible lead

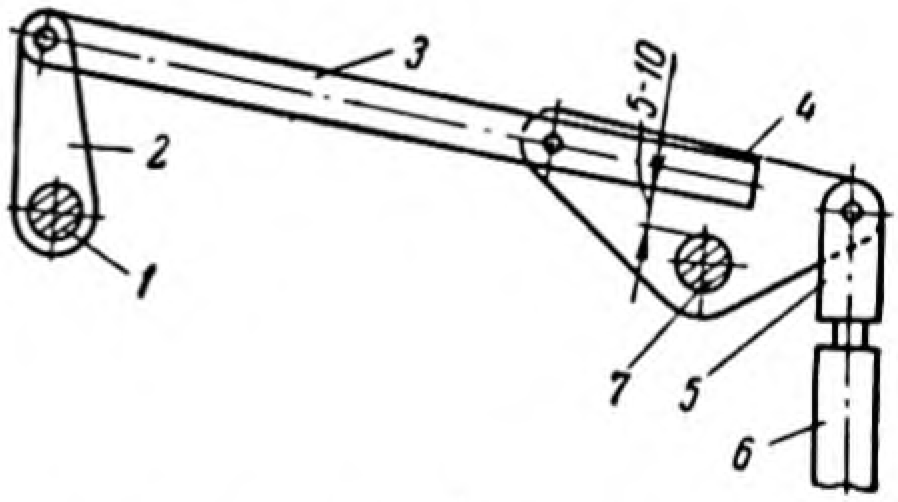


Fig. 198. Interlinkage of first-pole tie rod with operating mechanism tie rod:

1—actuating shaft of first phase; 2—actuating lever of first phase; 3—first-phase tie rod; 4—circuit-breaker actuating lever; 5—clevis; 6—operating-mechanism tie rod; 7—circuit-breaker actuating shaft

The angle of rotation of the auxiliary switch contacts is adjusted by altering the length of the tie-bar arm linking the switch and the operating mechanism or, if necessary, by varying the arm length on the auxiliary-switch lever which has a series of holes for the purpose. When necessary, the position of the lever on the shaft may be changed relative to the switch disk.

Normally the interlock contacts in the closing coil circuit must break at the very end of the stroke, and the break distance when the operating mechanism is closed should be 4 to 5 mm. The same break distance should appear between the contacts in the trip coil circuit when the circuit breaker is open.

Prior to putting a circuit breaker into service, it is necessary to check its electric heaters *10* (Fig. 192) for proper connection which should be parallel for 127-volt supply and series for 220-volt supply.

The resistance of the heaters must be adjusted so that their total power consumption is 600 ± 50 watts. This adjustment is accomplished by shifting the clamps on the six resistor stacks.

Problem. According to the data given in Fig. 191, make a laying-out drawing which will enable the builders to put in a concrete foundation for an MΓ-35 oil circuit breaker.

31. Mounting of an MΓ-110 Oil Circuit Breaker

The MΓ-110 is a separate-pole multitank minimum-oil circuit breaker of the 110-kv class for outdoor installation.

Each pole of this circuit breaker, without the operating mechanism and oil, weighs 1,000 kg and takes 200 kg of oil.

For the installation dimensions of this circuit breaker see Fig. 199. Its construction is shown in Fig. 200.

The MΓ-110 breaker is available with either three-pole or single-pole control. Our discussion will be concerned with a three-pole breaker unit which is operated by a ШПС-30 solenoid mechanism. This operating mechanism is identical in design with the ПС-30 (see Sec. 16), the only difference being that it is intended for outdoor installation and is housed in a cabinet. The ШПС-30 operating mechanism weighs 550 kg. Its general view and overall dimensions are shown in Fig. 199.

Take-down inspection and assembly before installation. The MΓ-110 oil circuit breaker comes from the manufacturer partially disassembled. The upper part of each pole (Fig. 201) is mounted on the support framework and filled with oil. Each pole is packed in a separate wooden box. The support insulators, operating mechanism, insulating actuating rod and other parts are also shipped separately packed.

Before installation, a circuit breaker is examined for broken porcelain and missing parts.

The three poles are lifted with a crane and placed on a common support frame which is secured to concrete foundation. The operating mechanism is mounted on the same foundation.

After the poles have been lifted in place on the welded frame, the panels *2* and *3* (Fig. 201) are removed, the interpole spacers *1* put

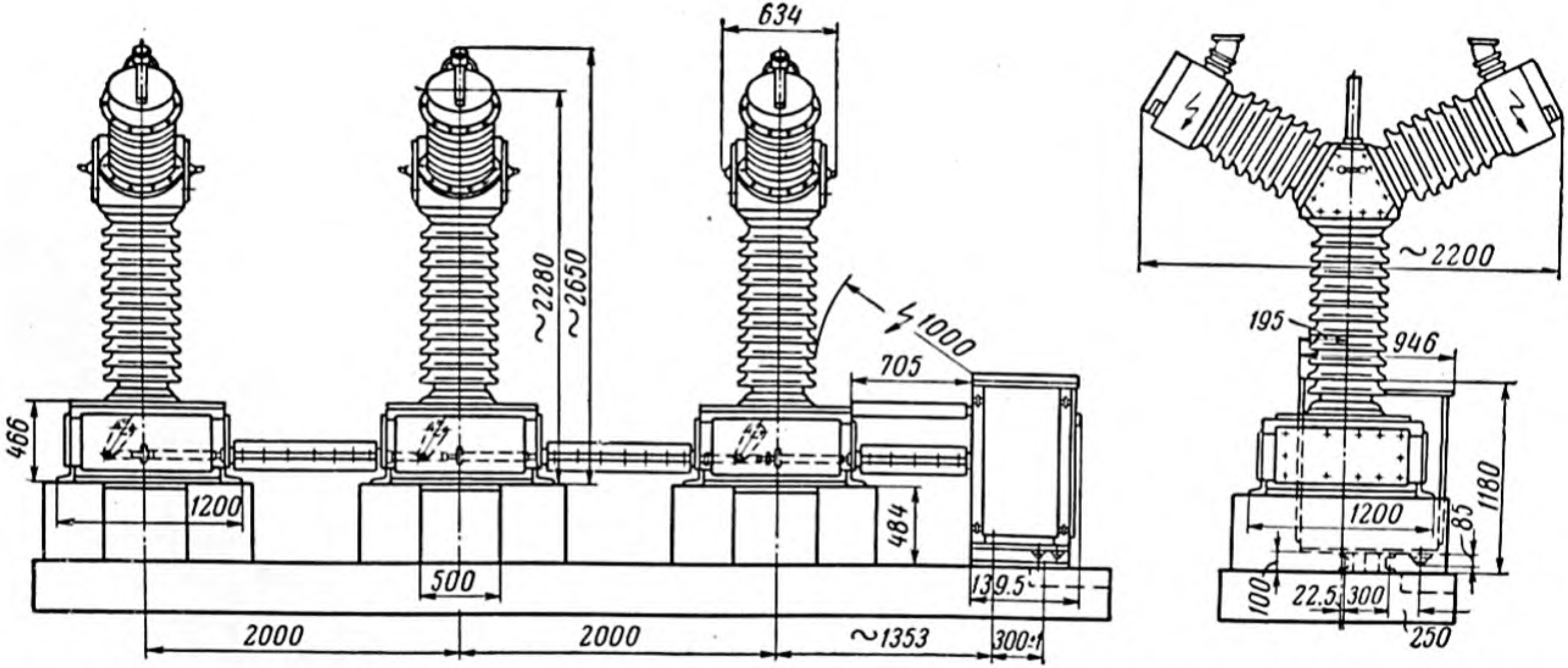


Fig. 199. General view and installation dimensions of the МГ-110 oil circuit breaker and ШПС-30 solenoid operating mechanism

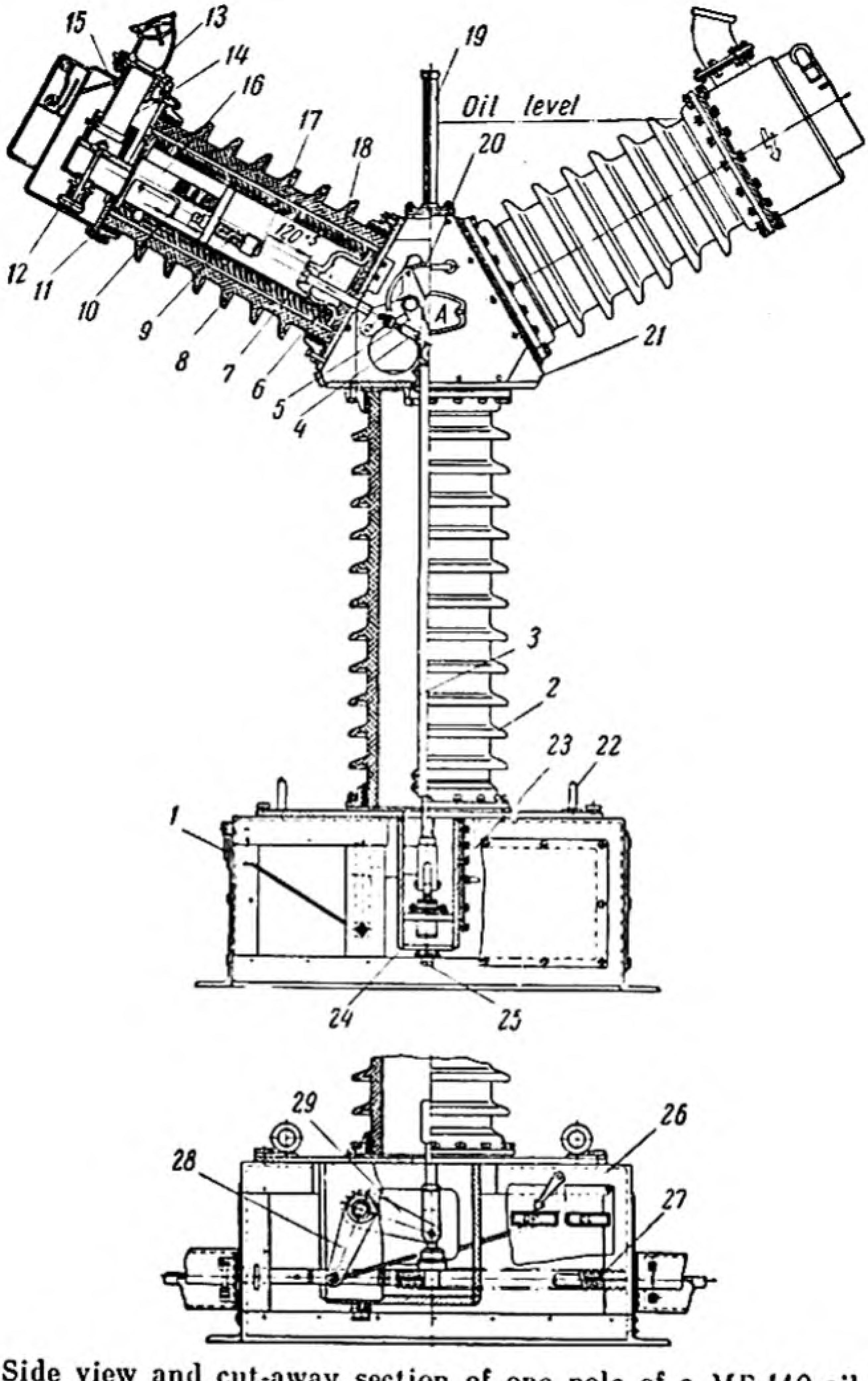


Fig. 200. Side view and cut-away section of one pole of a MΓ-110 oil circuit breaker:

1—base frame; *2*—porcelain support insulator; *3*—insulating rod; *4*—clevis; *5*—levers of moving-contact mechanism; *6*—flange; *7*—bakelised-paper sleeve; *8*—porcelain shell; *9*—spring; *10*—stationary contact; *11*—bolt securing housing to porcelain shell flange; *12*—spring valve; *13*—relief valve; *14*—intermediate tube; *15*—housing of arc-control unit; *16*—insulating barrier; *17*—intermediate contact; *18*—moving contact rod; *19*—oil level gauge; *20*—flexible lead; *21*—housing cover; *22*—lifting eye; *23*—lower actuating-linkage housing; *24*—oil dashpot; *25*—oil drain fitting; *26*—circuit-breaker position indicator; *27*—opening springs; *28*—external actuating lever of lower actuating-linkage housing; *29*—inside actuating lever of lower actuating-linkage housing

in place and brace angles *7* installed between the first pole and the operating mechanism (Fig. 202).

The blind flanges *8* (Fig. 201) which prevent the oil from being splashed out in transit are removed, and relief valves are fitted instead, with the rubber gaskets left in place. The plugs *9* are also replaced by the gas vents sealed at the joint with red-lead and tow.

To obtain access to the oil drain fittings *25* (Fig. 200), the blind plates closing off the pole frames at the bottom are removed. Screwing-in the drain bush opens the fitting and the oil is drained from each pole.

The nuts are then unscrewed from their bolts *5* (Fig. 201), the upper parts of the poles are removed and placed on make-shift supports. When doing so, care must be taken not to damage the barriers secured to the bodies *7* from beneath.

The intermediate flanges *11* are only necessary in transit and are removed by unscrewing the nuts off the bolts *4*.

The upper and lower rubber gaskets are next removed, thoroughly washed in petrol, coated with glyptal varnish on both sides, and dried in air for at least 3 hours.

The dried lower rubber gaskets are placed on the base, and the support insulators *2* (Fig. 200) are seated on them after the internal surfaces of the insulators have been wiped clean with rags moistened with petrol. The nuts should be tightened in turn round the circumference, giving each nut not more than one revolution at a time, or else the insulator may be broken by unbalanced tightening.

The rods *3* should be wiped with soft dry lint-free rags, passed through the support insulators, with the threaded end down, and screwed at least 24 mm into the clevises on the internal levers within the transmission linkage housings. When they are properly screwed in place, the centre line of the hole in the upper end of each rod must be 86 mm above the surface of the upper flange of the insulator when the breaker is fully opened.

The dried rubber gaskets may now be placed on the support insulators and the upper parts of the poles mounted on them. The nuts should be tightened with the precautions stated above, and the upper ends of the rods should slip in between the shackles *2* (Fig. 203).

The length of the rod is then finally adjusted by screwing the forks on their ends either in or out, so that when the breaker is fully opened the dimension *A* is 97 mm for the first pole, 95 mm for the second, and 93 mm for the third pole. After this the upper end piece of the rod is linked with the shackles *2* by means of pins *1*.

In transit the guides and springs *4* (Fig. 202) as well as the forks are tied with wire to the external levers *28* of the lower transmission linkage housings (Fig. 200). Prior to any work on the operating mechanism, the wire must be removed, the pivot pins *3* (Fig. 202) pulled

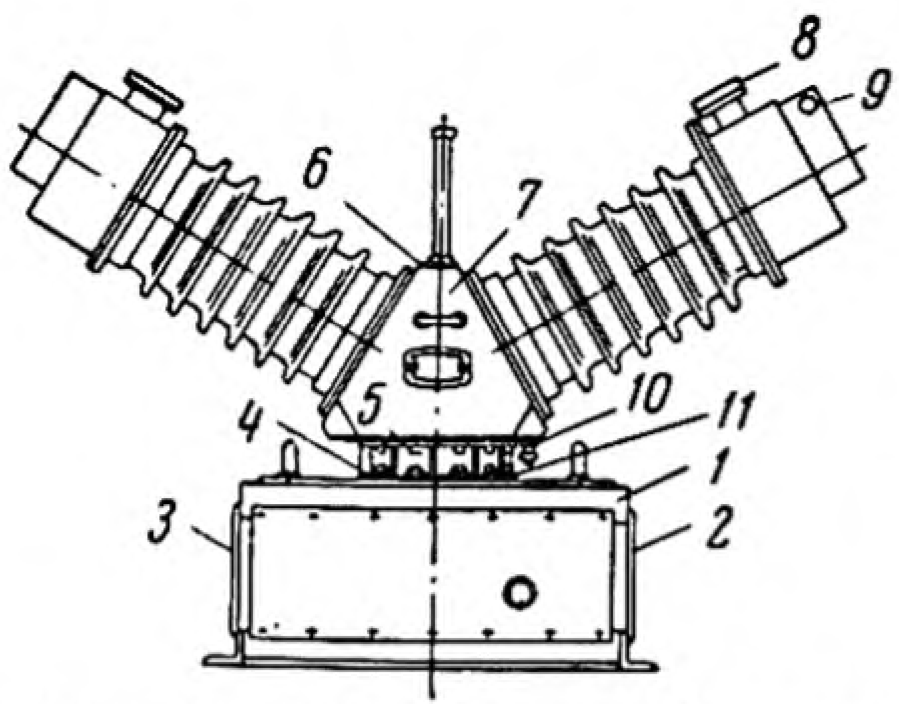


Fig. 201. Upper part of pole secured on support frame for transportation:

1—support frame; 2,3—panel plates; 4—fixing bolts; 5—upper fixing bolts; 6—rubber gasket under oil gauge flange; 7—body piece; 8—blind flange in place of relief valve; 9—plug in place of gas-vent pipe; 10—oil drain fitting; 11—intermediate flanges

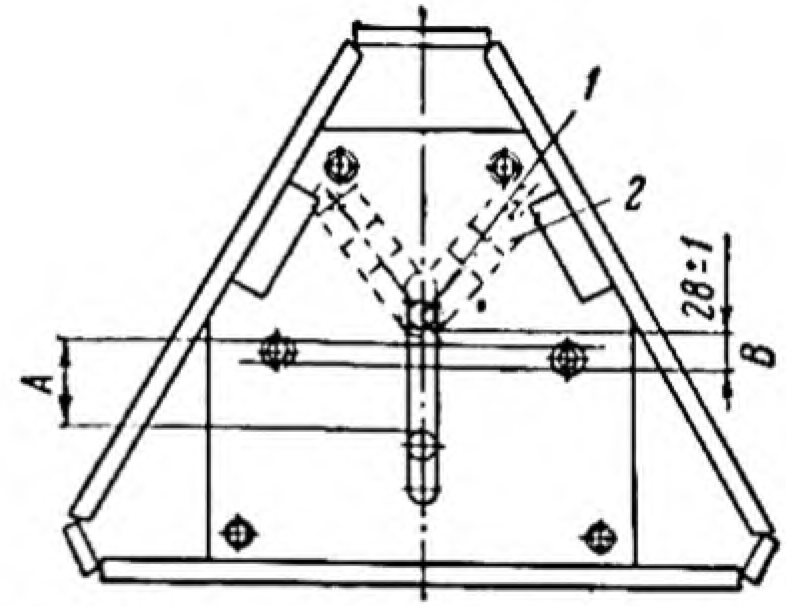


Fig. 203. Adjustment dimensions for closed and open positions of linkage:

1—pivot pin; 2—shackle

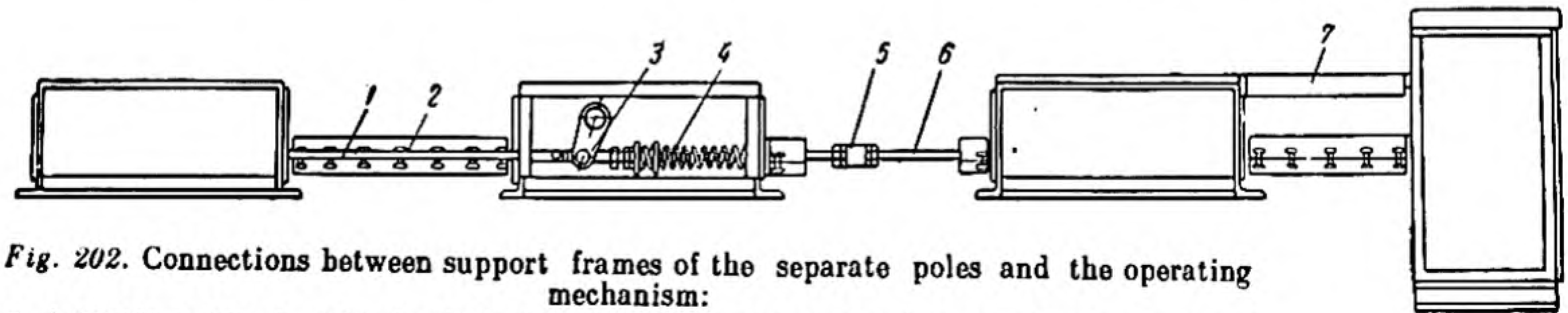


Fig. 202. Connections between support frames of the separate poles and the operating mechanism:

1—interpole spacer; 2—nuts; 3—pivot pin connecting forked piece with external lever; 4—spring and guide member; 5—turnbuckle; 6—tie rod; 7—angle-iron brace

out, and the guide forks connected with the external levers by means of the pivot pins.

The side walls are then removed from the operating-mechanism cabinet, and the tie rods *6* are installed between the poles and the operating mechanism while the poles are open. Each rod should have a nut and spring washer on each end for locking after adjustment. The length of the tie rod to the operating mechanism should be such that a clearance of about 10 mm is left between the striker of the push rod *4* (Fig. 204) and the roller *6* in the operating mechanism in the open condition.

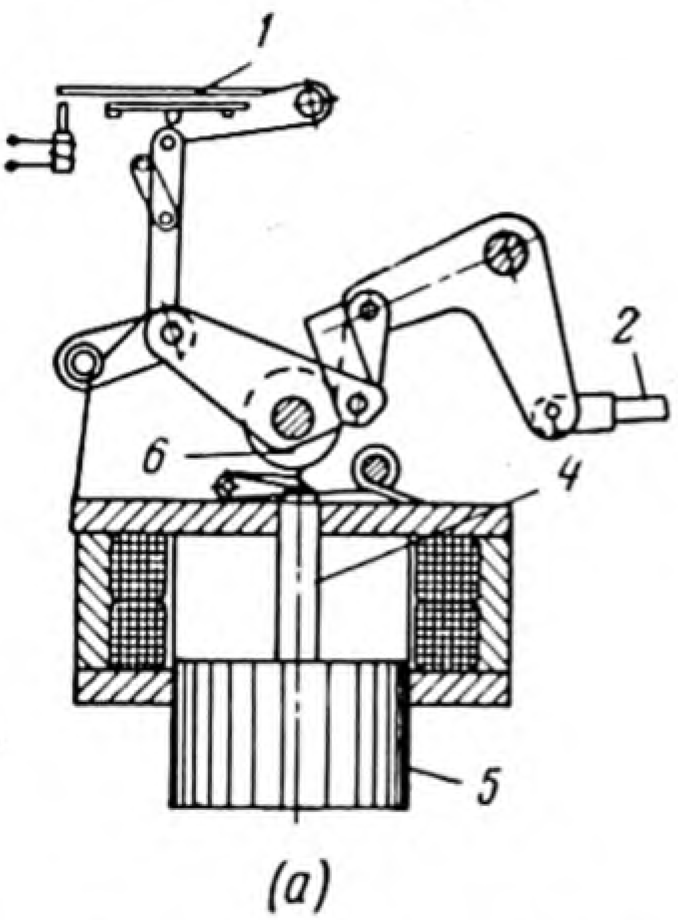


Fig. 204. Linkage of ПС-30 operating mechanism:
a—open position; *b*—closed position: *1*—latch plate; *2*—tie rod to circuit breaker; *3*—hold-in catch; *4*—push rod; *5*—operating-mechanism closing coil; *6*—roller

Adjustment of the circuit breaker and operating mechanism for joint operation. A screw jack is placed under the plunger of the operating mechanism, and the breaker is closed. According to the manufacturer's instructions, the distance *B* at the end of a closing stroke should be 28 ± 1 mm in all three poles (Fig. 203).

It may so happen that this distance will be reached in one of the poles before the closing stroke is completed. If so, the closing should be discontinued and the tie rod to the operating mechanism should be made longer by means of the turnbuckle (omitted in the figure), after which the closing operation may be continued.

Final adjustment of the three poles is accomplished in the closed position with the turnbuckles *5* (Fig. 202) and the turnbuckles on the tie rod to the operating mechanism, with the screw jack slightly

lowered in order that the pivot pin of the roller *6* (Fig. 204) can bear on the hold-in catch *3*.

After the adjustment, the lock nuts on the tie rods should be fully tightened.

Using a test lamp, the in-contact travel of the contacts is then checked in the three poles. This is considered normal if the pivot pin *1* (Fig. 203) moves 17 to 19 mm after the lamp lights up and before the contacts are fully closed.

It should be borne in mind that when the lower transmission linkage housings are not filled with oil, the breaker should be opened slowly in order to avoid damage to the breaker mechanism, as there is no oil to cushion the shock. For the same reason the latch *1* in the operating mechanism (Fig. 204) should be clamped or tied during these trial openings and adjustment. To open the breaker, the plunger of the operating mechanism must first be raised with a screw jack almost as far as it will go, the operating mechanism should be driven past its closed position so that the pivot pin of the roller *6* rises slightly above the hold-in catch *3*; the catch should then be forced away with a metal rod so that it is out of the roller's way when it is moving downward; the pawl of the screw jack can now be reversed and the circuit breaker slowly opened by lowering the plunger *5*.

After the trial closing operations, the covers of the transmission linkage housings are put back and secured in place, and each pole is filled with as much as 20 kg of oil.

Trial power operation of the circuit breaker. The breaker should first be opened and closed two or three times at a reduced (80 per cent) voltage and the dimensions shown in Fig. 203 should be rechecked. The tolerance on the dimensions corresponding to the open position is ± 3 mm. For a check on these dimensions, the interpole tie rods should be pulled by hand to bring the mechanism against the limit stop of the open position.

When finally adjusted, the breaker and its operating mechanism are given a series of closing and opening operations including up to five cycles at a voltage reduced to 80 per cent of the rated value, as many cycles at full voltage, and three cycles at 110 per cent of the rated voltage.

If the closing coils of the operating mechanism are not to be overheated, short time intervals should be made between the adjustments and trial operations.

Filling of the circuit breaker with transformer oil. Before the breaker may be filled with oil, the covers of the housings should be put back and secured in place. Oil should be poured in until its level is between the marks on the oil gauge. The lower mark is for an oil temperature of -40°C and the upper, for $+35$°C.

Oil is usually poured through the opening of one of the relief valves, for which purpose at least one of them should be removed on each pole. However, this purpose can also be served by the oil drain fittings in the lower transmission linkage housings.

Electric heater adjustment. The breaker housing contains a set of electric heaters which must be connected in parallel for 110/127-v supply and in series for 220-v supply. After a check on their connection the resistance of the heaters must be adjusted by moving the

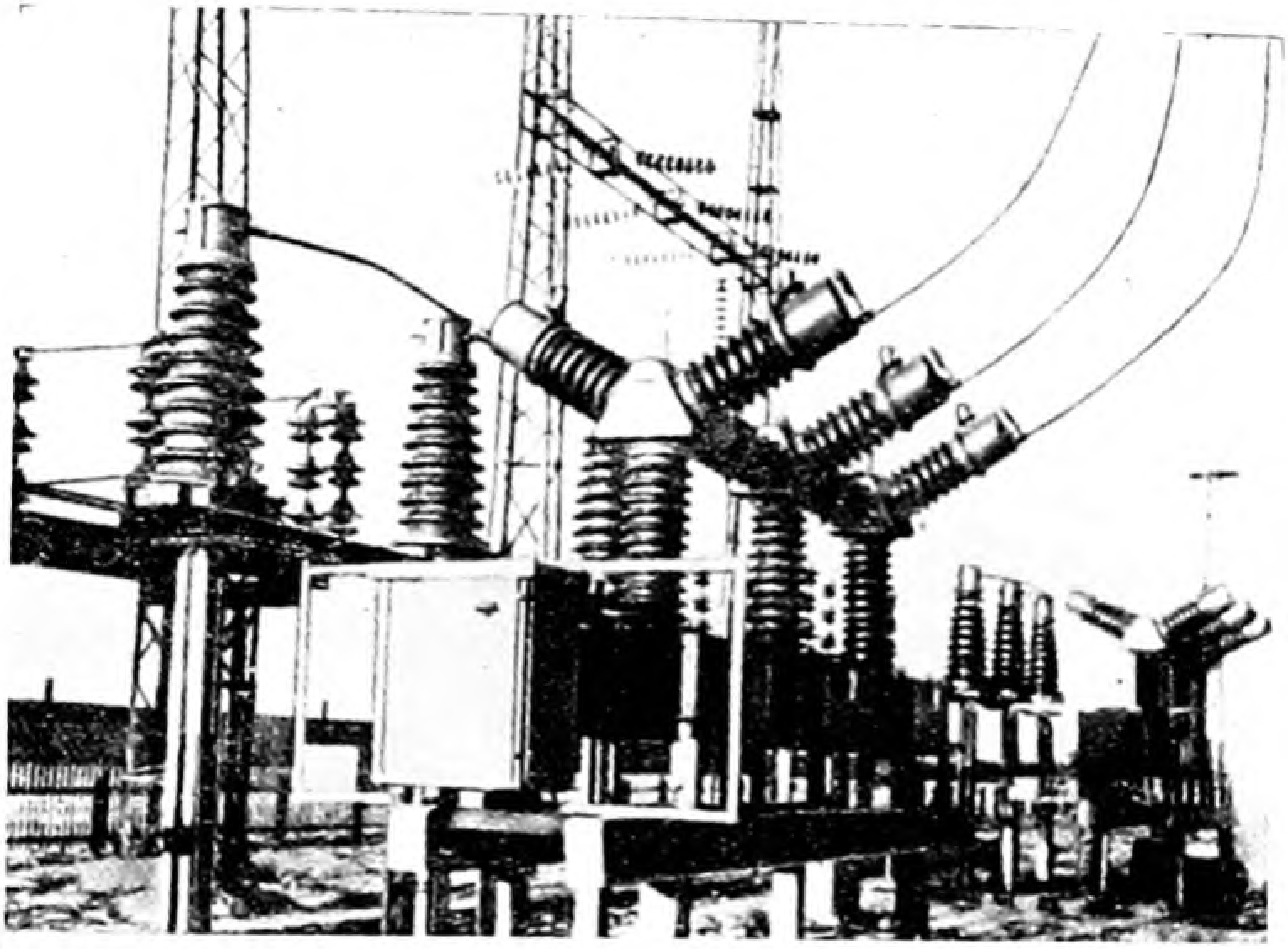


Fig. 205. МГ-110 oil circuit breaker in a substation

clamps on the heater tubes so that their power consumption is 400 to 440 watts.

In conclusion, the panels are put back on the breaker and operating mechanism, and the breaker frame and the operating-mechanism cabinet are connected to the earthing system.

A general view of an МГ-110 oil circuit breaker is shown in Fig. 205.

Problem. Write up the installation of an МГ-110 oil circuit breaker for the case shown in Fig. 205.

32. Mounting of an МКП-110 Oil Circuit Breaker

The МКП-110 is a 110-kv multitank, substation bulk-oil circuit breaker designed for outdoor installation.

The installation dimensions of this circuit breaker are given in Fig. 206. The internal construction is shown in Figs 207 and 208.

The total weight of the circuit breaker (without terminal bushings and oil) is 9,830 kg. It takes 8,500 kg of oil to fill the circuit breaker.

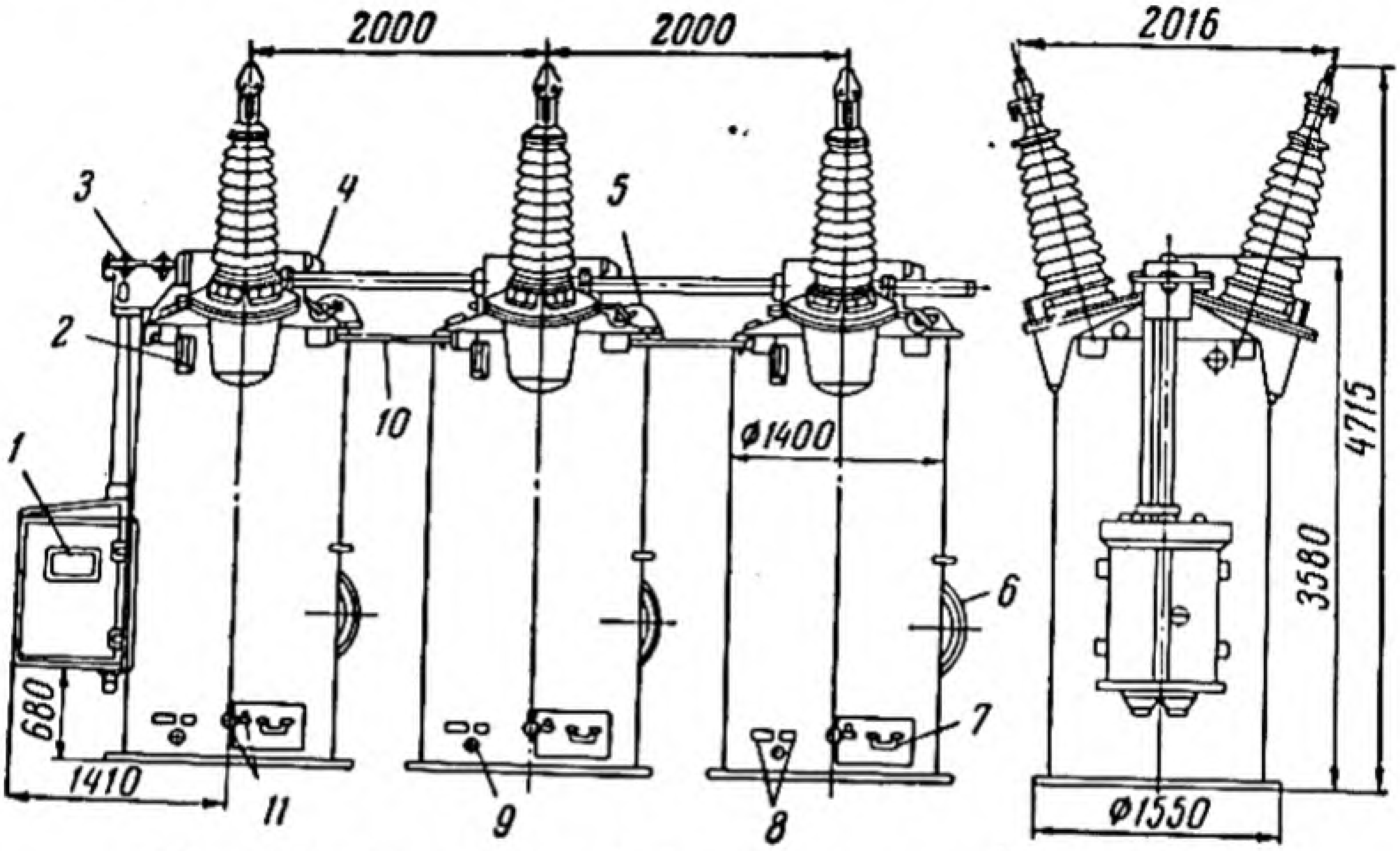


Fig. 206. General view of the МКП-110 oil circuit breaker:

1—ШПЭ-33 solenoid operating mechanism; *2*—oil level gauge; *3*—circuit breaker position indicator; *4*—gas vent; *5*—relief valve; *6*—manhole for access to tank; *7*—access opening for doing work under tank; *8*—nameplates bearing circuit breaker and bushing current transformer ratings; *9*—earthing bolt; *10*—between-tank connectors; *11*—oil drain cock

This type of circuit breaker is available for three-phase and single-phase control and comes complete with a ШПЭ-33 solenoid operating mechanism weighing 595 kg.

Inspection of the circuit breaker before installation. When an МКП-110 breaker arrives on site, it should be inspected for damaged crating and packing boxes and for missing parts against the attached packing lists.

Only the breaker tanks may be left out of doors; all the other parts should be stored in a heated room at a temperature of not less than +5°C.

Before installation, the circuit breaker is inspected visually for damaged assemblies and parts, and cleaned thoroughly to remove dust deposited in transit.

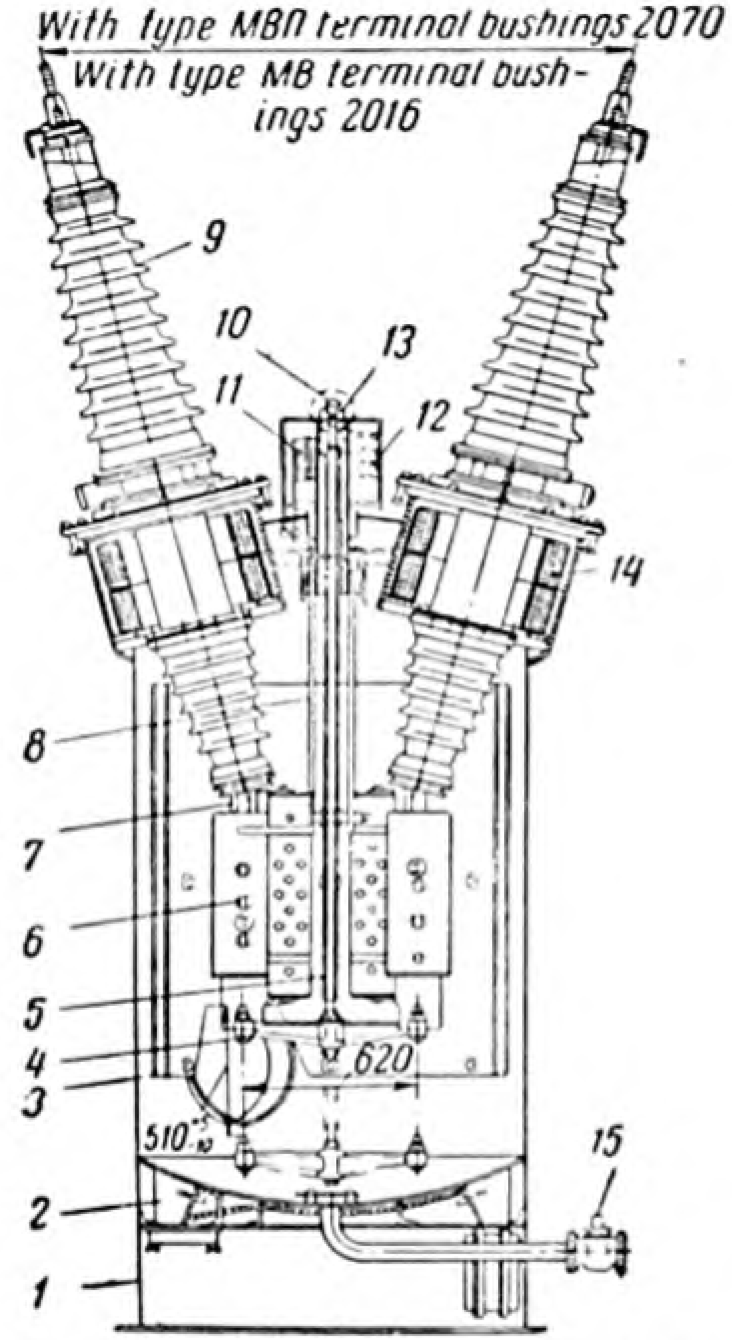


Fig. 207. Cross section through one phase of the circuit breaker:

1—tank; *2*—oil heating equipment; *3*—tank insulation; *4*—moving-contact cross-arm; *5*—insulating lift rod; *6*—arc-control assembly; *7*—contact rod; *8*—guide arrangement; *9*—terminal bushing; *10*—stop screw; *11*—terminals for connection of current transformer leads; *12*—actuating linkage; *13*—cap piece; *14*—bushing current transformer; *15*—oil drain cock

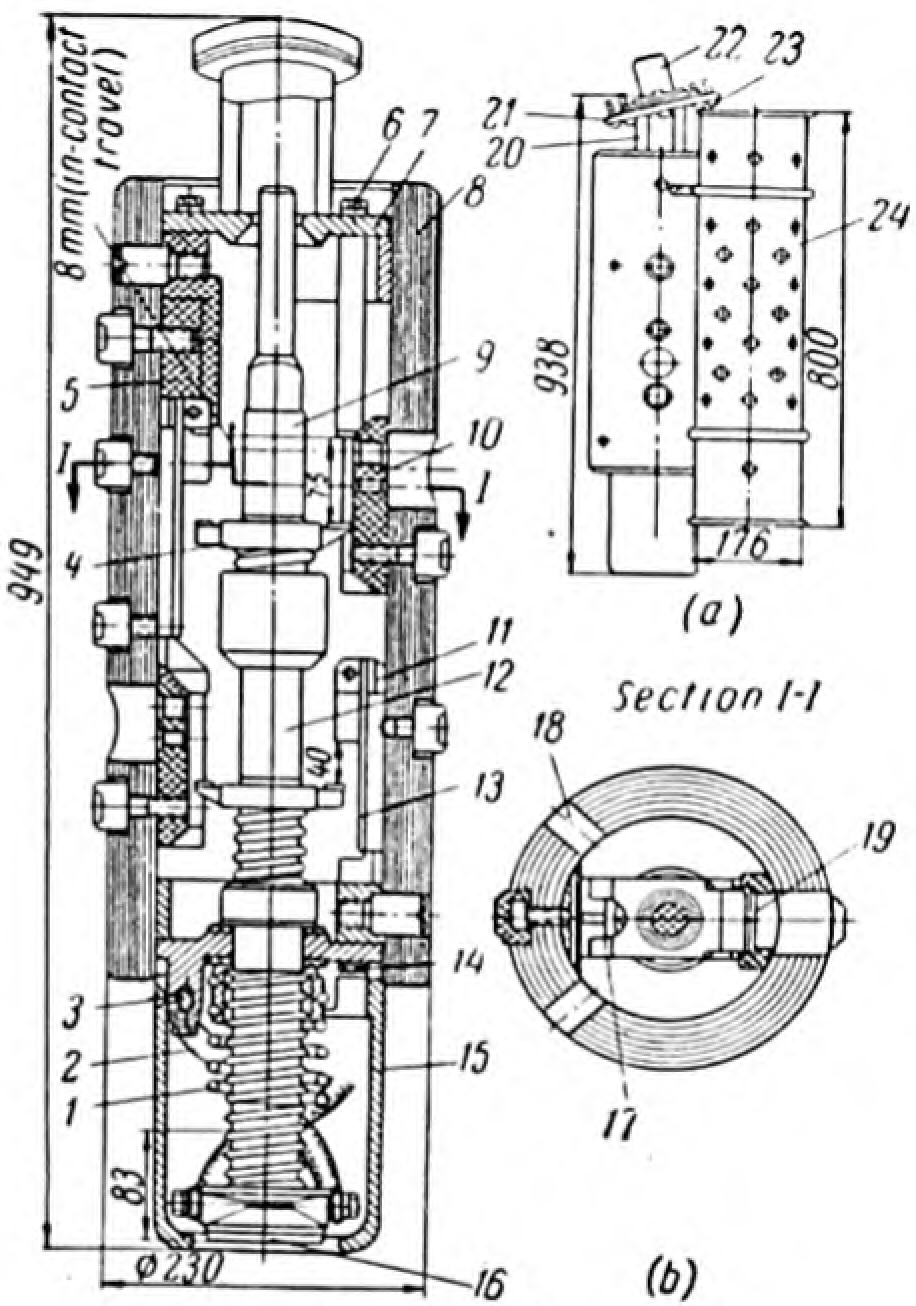


Fig. 208. Arc-control assembly:

a—general view; *b*—arc-control chamber: *1*—spring; *2*—flexible lead; *3*—screw; *4*—jumper piece; *5*—insulating block of upper stationary contact; *6*—bolt; *7*—cover; *8*—bakelised cylinder; *9*—moving insulating rod; *10*—discharge openings; *11*—stationary contacts; *12*—contact stalk; *13*—insulating block; *14*—screw; *15*—shield; *16*—lower contact; *17*—generating gap contacts; *18*—additional ports for pressure relief; *19*—break-gap contact; *20*—holder; *21*—pressure ring; *22*—contact sleeve; *23*—bolt; *24*—shunting resistors

Mounting and assembly of the circuit breaker. The circuit breaker is carried to its foundation on a railway platform, or on a suitable truck riding a rail track, or is moved on skids.

Fig. 209 shows the layout of the anchor bolts in the foundation of this circuit breaker.

Each phase assembly of the circuit breaker can be conveniently placed on the foundation by a crane (Fig. 210). If a crane is not available, each phase assembly can be moved onto the foundation over a ramp consisting of railway sleepers, square timber and boards 50 mm thick.

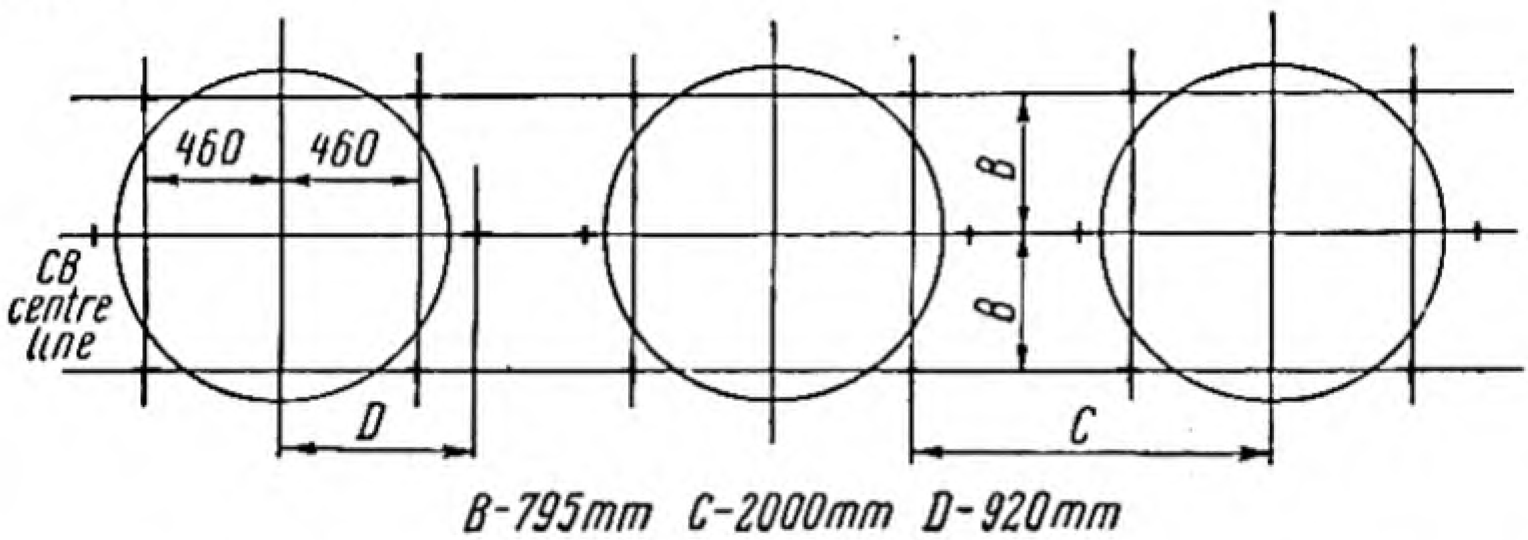


Fig. 209. Layout of anchor bolts for МКП-110 oil circuit breaker

The breaker tanks must be placed on the foundation to the markings on the tanks and the levers of the operating mechanism. After the tanks of all three phase assemblies are placed on the foundation, they are levelled and aligned. For this purpose the hoods *3* are removed from the actuating linkage housings (Fig. 211), a steel wire is strung along the centre line of the three phase assemblies, and the tanks are levelled and aligned so that the centre line of each housing coincides with the steel wire. The distance between the phase assemblies is also checked. For greater stability, pads of boiler steel 8 to 10 mm thick are slipped under the tank feet.

After the levelling and alignment, the anchor bolts are inserted in the holes in the tank feet so that they hang in the wells provided for them in the foundation, and cement mortar is poured around them.

Next the phases are connected into a three-pole unit. For this, the tie rods *6* of the first and second poles are connected together by means of a coupler *4* (Fig. 212) provided with a left-hand and a right-hand thread so that the gap between the lever *7* of the breaker mechanism and the stop screw *1* (Fig. 211) is 1.5 to 2 mm. The tie rod must be screwed at least 20 mm into the coupler at each end.

Then the tie rods between the second and third poles are joined together so that the gap between the lever *7* and the stop screw *1* in the breaker mechanism of the third pole is 1.5 to 2 mm.

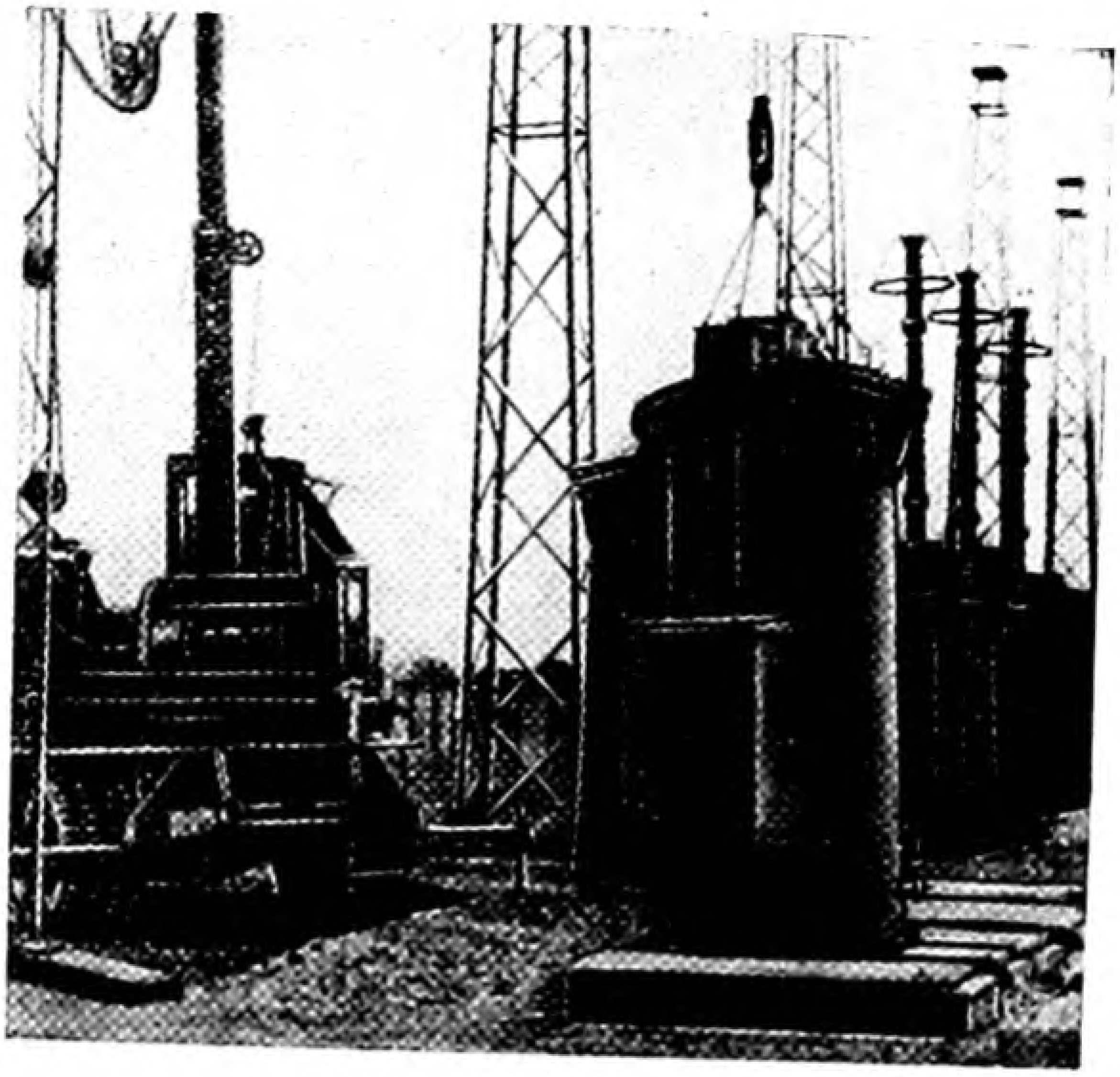


Fig. 210. Placing of an МКП-110 oil circuit breaker with a mobile crane

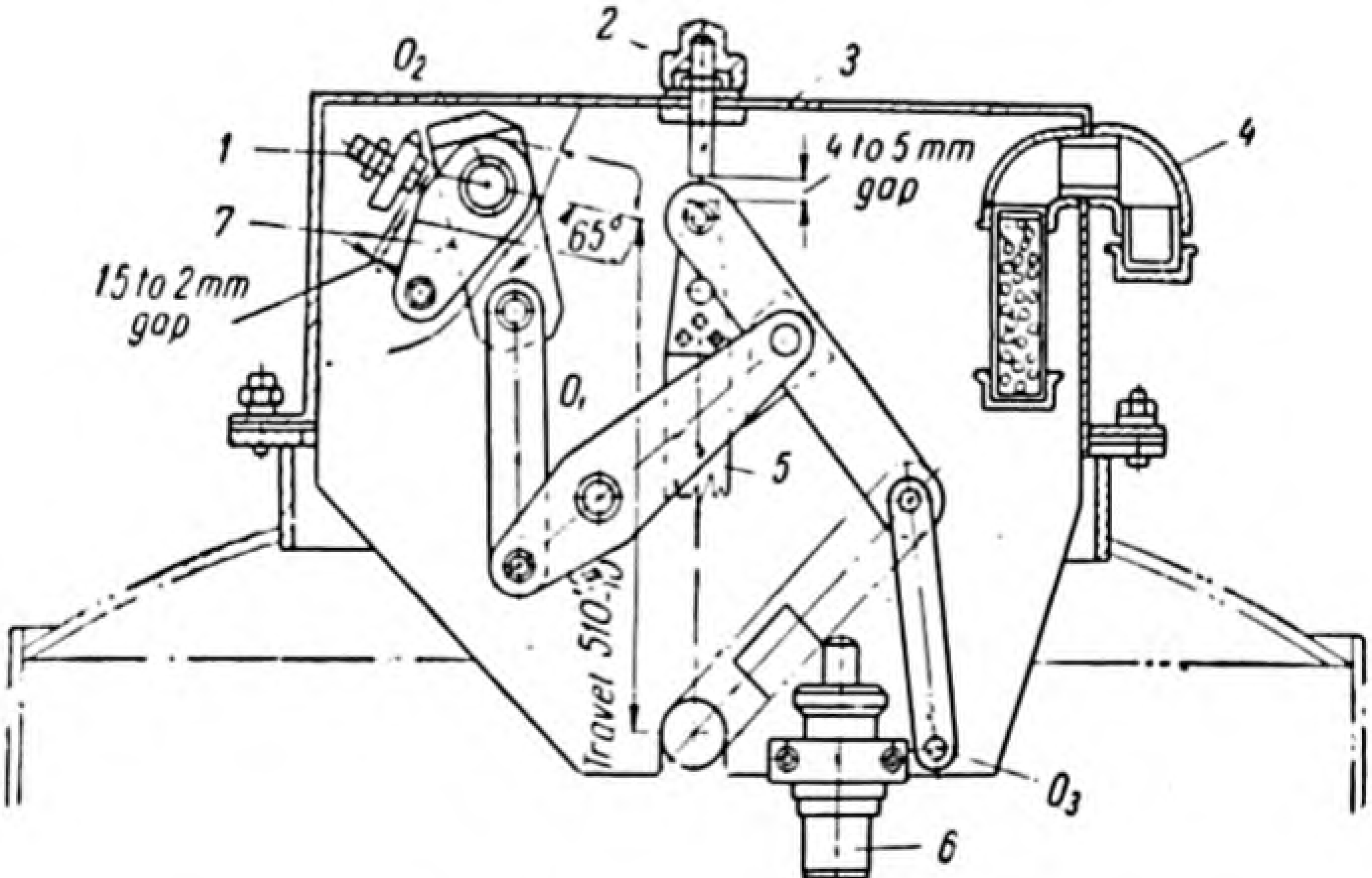


Fig. 211. Actuating linkage:
1 and *2*—stop screws; *3*—hood; *4*—gas vent; *5*—insulating lift rod; *6*—oil dashpot; *7*—actuating lever (item *9* in Fig. 212)

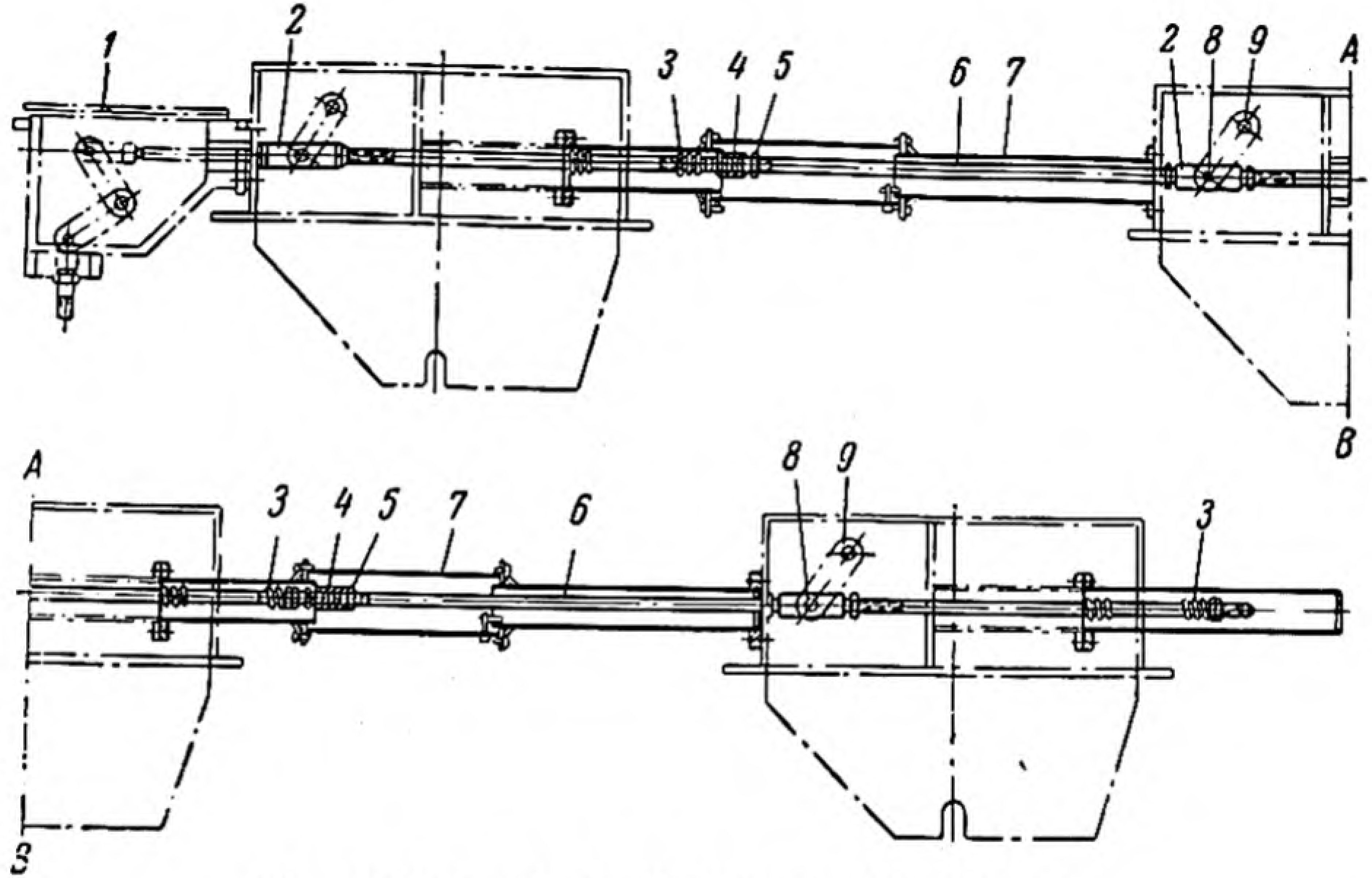


Fig. 212. **External actuating linkage of circuit breaker:**

1—angle housing with position indicator; 2—forked member; 3—opening spring; 4—coupler; 5—lock nut; 6—tie rod; 7—housing; 8—pivot pin; 9—actuating lever (item 7 in Fig. 211)

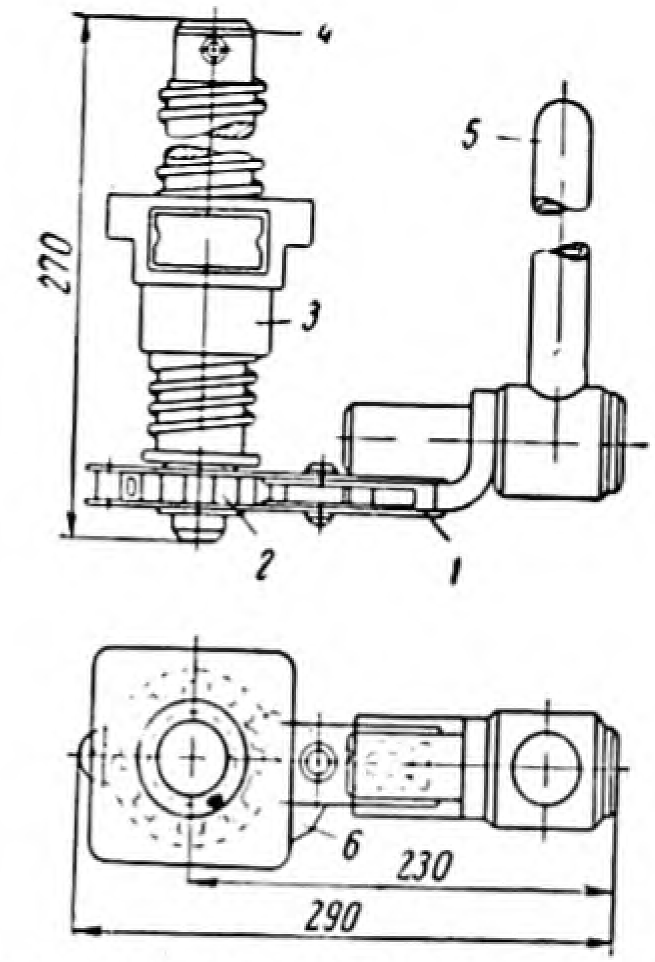


Fig. 213. Screw jack for manual check closing and opening of breaker:

1—body; 2—ratchet wheel; 3—nut; 4—nose; 5—handle; 6—pawl

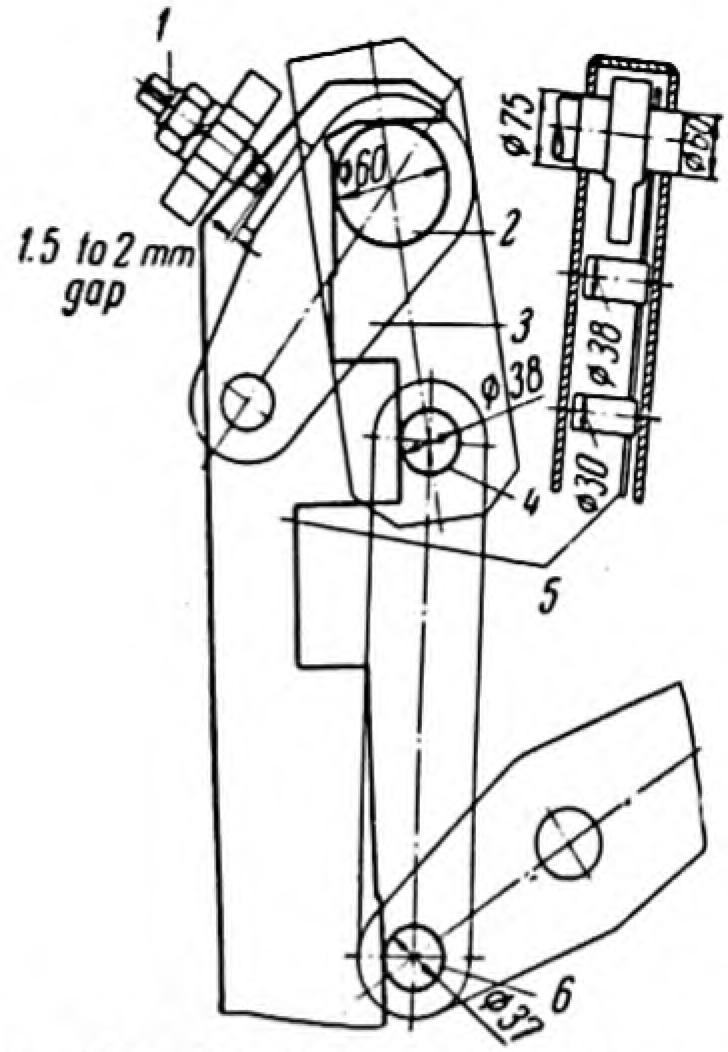


Fig. 215. Checking of МКП-110 circuit-breaker actuating linkage:

1—stop screw; 2—main shaft of actuating linkage; 3—actuating lever; 4—middle pivot pin; 5—template; 6—lower pivot pin

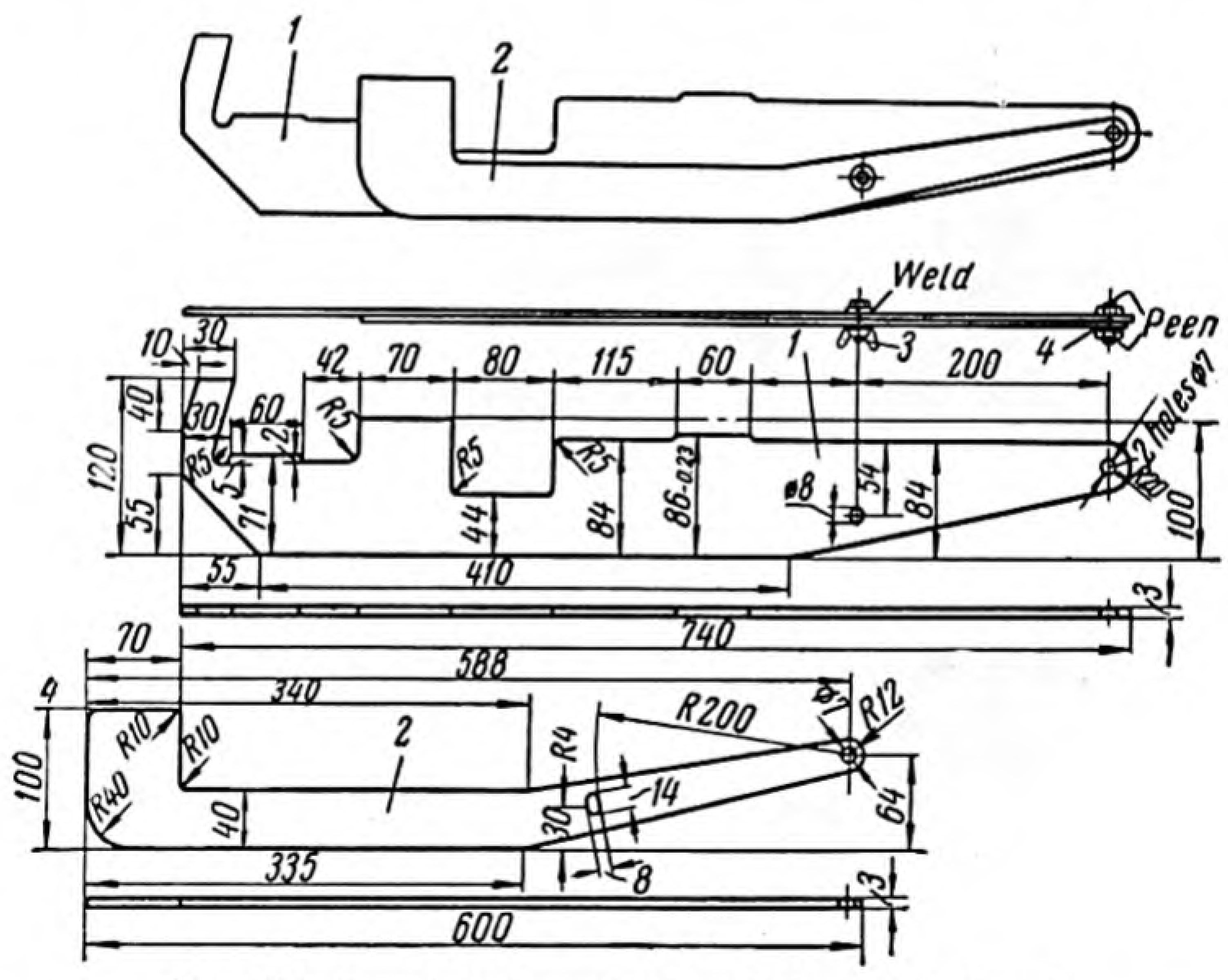


Fig. 214. Template for actuating linkage adjustment:

1—template, 2—indicator of template; 3—M7 wing nut; 4—M6 nut

The circuit breaker is next closed by means of a screw jack (Fig. 213) and checked for the dead-centre position with a template (Fig. 214). When properly adjusted, the middle pivot of the three forming a dead-centre (Fig. 215) in the actuating linkage of each pole is 3 to 4 mm off the dead-centre position.

The total travel of the cross-arm should be 510^{-5}_{+10} mm.

The breaker is then fitted with the current transformers (Fig. 216) which should first be given a standard check.

Prior to installation, the bottom and walls of the current transformer chamber are lined with oil-resistant rubber. The current transformers are lifted by a truck crane and the lifting accessory shown in Fig. 217. The current transformer is secured in place with wooden wedges, and its leads are given servings of herringbone or taffeta tape.

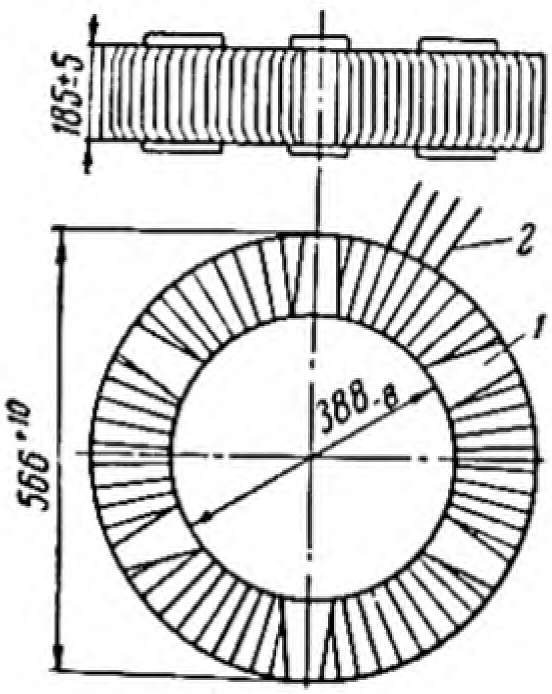


Fig. 216. Bushing-type current transformer:
1—wedge; 2—leads

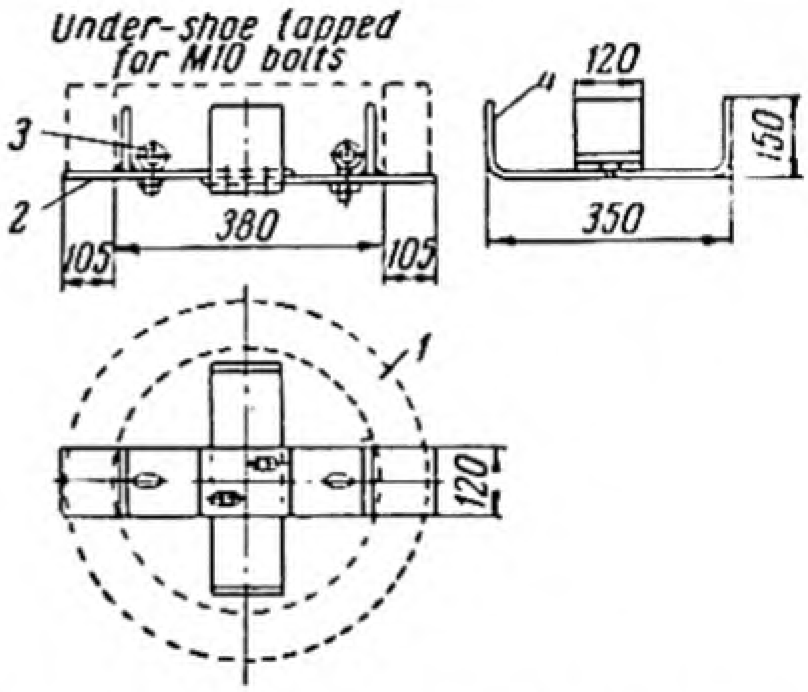


Fig. 217. Accessory for lifting of current transformer:
1—current transformer; 2—plate; 3—lifting ring; 4—shoe

The current transformers are followed by the bushings (Fig. 218) which are also first inspected for broken porcelain, cemented joints and current-conducting terminals.

The bushings should also be subjected to an electrical test and be dried out if the results prove unsatisfactory. For lifting, a bushing should be suspended from the hook of a truck crane as shown in Fig. 218*b*. When lifting, the bushing should be inclined from the vertical by means of block and tackle *3* as it will be mounted on the breaker cover, i.e., through about 15 degrees. The bushing should be inclined in the direction of its breather tube (Fig. 218*a*) and the sludge plug located in the flange of the expansion chamber at the top of the bushing.

In mounting a bushing, care must be taken not to damage the tank lining with the lower porcelain shell. Should the shell touch the top sheet of the tank lining, the latter should be trimmed so as to leave a clearance of 20 to 30 mm between it and the porcelain shell.

The bushing is next tentatively tilted by loosening the nuts on one side and tightening them on the other side. The tilt is finally adjusted and the bushing is tightened during the final adjustment of the circuit breaker.

In transit, the breather-tube hole is closed with a screw and washer. Once the bushing is put in place, the screw must be removed and replaced by the breather tube with its end pointing downward.

The thread on the lower end of the bushing conductor must be thoroughly cleaned of dirt and oxide. It is considered best to use a

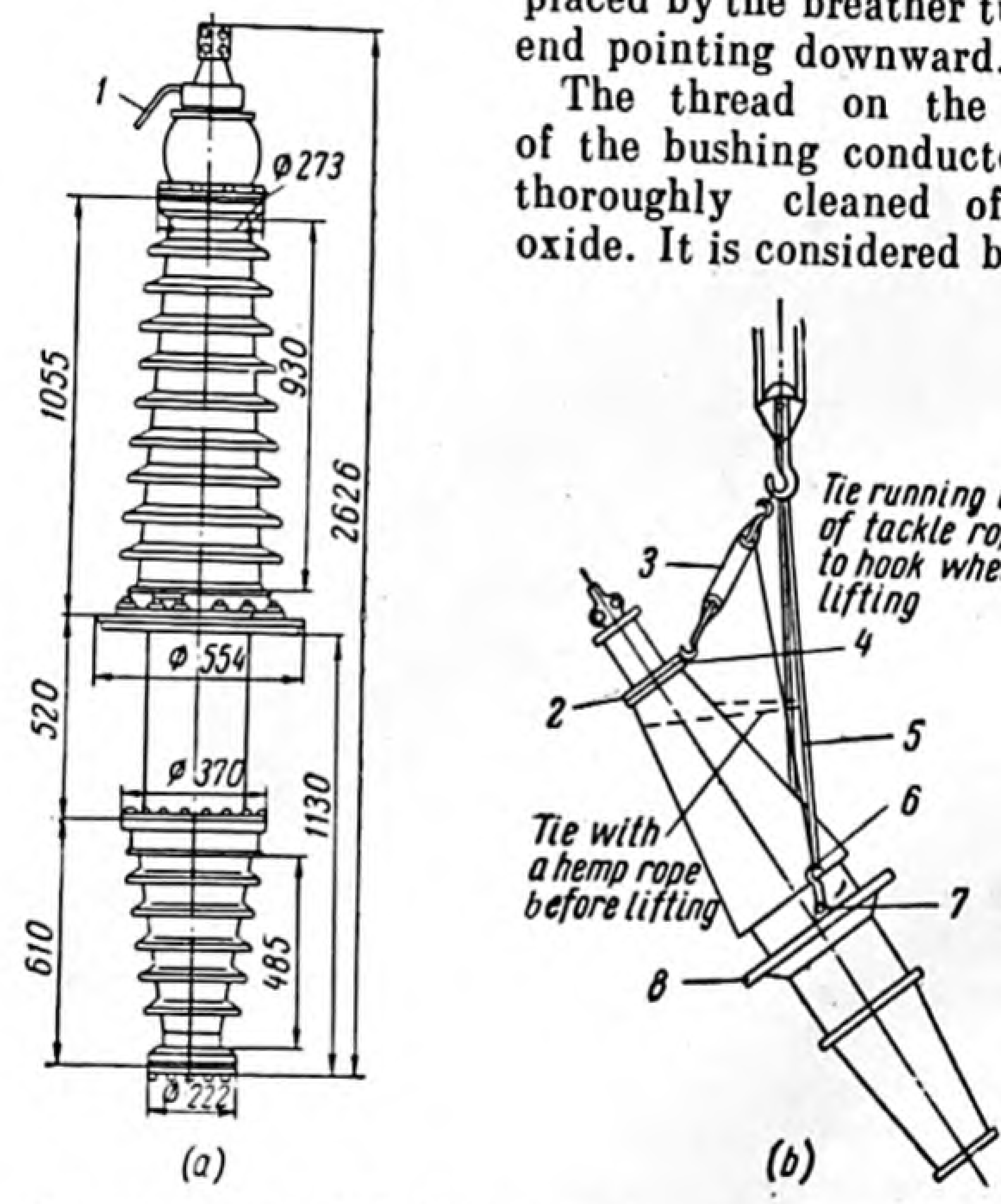


Fig. 218. Terminal bushing and arrangement of lifting tackle:

a — terminal bushing; *b* — lifting tackle arrangement: *1*—breather tube; *2*—clamp; *3*—block and tackle; *4*—clamp eye; *5*—sling rope; *6*—hook; *7*—lifting ring; *8*—holder

special chaser die for this purpose. As a result, a low contact resistance will be obtained between the rod *7* of the bushing *9* (see Fig. 207) and the contact sleeve *22* (see Fig. 208), to which the holder *20* of the arc-control assembly is attached.

The bushings are followed by the arc-control chambers which should first be subjected to thorough inspection. For this, the bolts *3* are removed (see Fig. 208), shields *15* slipped off, screws *14* unscrewed, and the contact assembly removed for examination. If dust is detected inside the chamber, it should be blown out with compressed air or removed with a clean dry rag. Minor defects on the insulating parts may be remedied by cleaning and subsequent coating with oil varnish.

When the rod element moves in the chamber, the movable copper flexible leads *2* should follow with ease.

Full travel of the moving system of the arc-control chamber should be anywhere between 83 and 85 mm, and that of the contacts, between 8 and 10 mm.

To inspect the shunting resistors *24*, first the contact leads are disconnected and the end covers of the protective case are removed. Then the inner cylinder carrying the resistance coil is taken out and examined for breaks, shorted turns, and reliable contact at the connections.

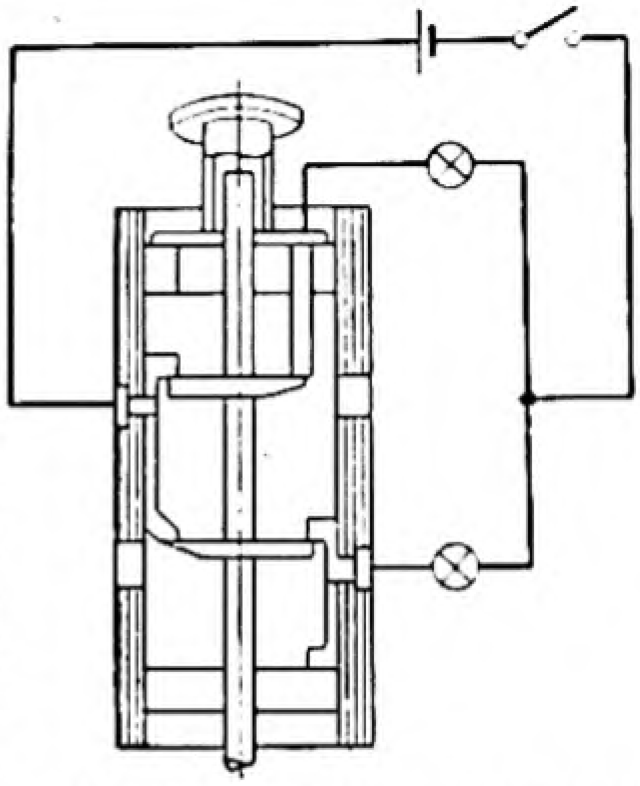


Fig. 219 Checking contacts in one arc-control chamber for simultaneous closing and opening

Shorted turns must be separated and spaced about 0.8 mm apart. The shunt is then assembled and checked for its resistance, which should be 750 to 770 ohms. This measurement is taken with direct current.

Now the contact assemblies and shunts are put back in place, following which the travel of the moving contacts is measured and the contacts are adjusted for simultaneous closing and opening within each pole.

The instant of contact closure is checked by use of the circuit arrangement given in Fig. 219, which takes into account the fact that this apparatus has a double-break arc-control system.

The lamps in the test circuit, on lighting simultaneously, indicate that the contacts in the arc-control chambers close and open simultaneously. The make tolerance is 1 mm, and excessive discrepancy can be reduced by adjusting the length of the candle-type moving contact *1* (Fig. 220).

After the adjustment the candle-moving contact on the cross-arms and the cross-arms on the lift rods are drilled and locked with nuts and set screws. The clearance between the upper part of the lift rod head and the limit stop should be 4 to 5 mm (see Fig. 211).

Now the bolts on the bushing flanges can be finally tightened, giving each a quarter of a turn at a time. When the pressure on the

gasket compresses it to 50 to 60 per cent of its original thickness, the tightening of the bolts should be stopped.

Before the circuit breaker is filled with oil, a closing operation is performed after which all the bolted and screwed joints should be checked. All loose joints should be tightened, locked with nuts, etc. Following this, all the rubbing parts are lubricated. Special commissioning crews then check the operating mechanism auxiliary switch contacts and the speed of breaker closing.

The circuit breakers are put into service after a series of trial closings.

A general view of an installed МКП-110 oil circuit breaker is shown in Fig. 221.

Problem. Write up an operation sequence for mounting an МКП-110 oil circuit breaker.

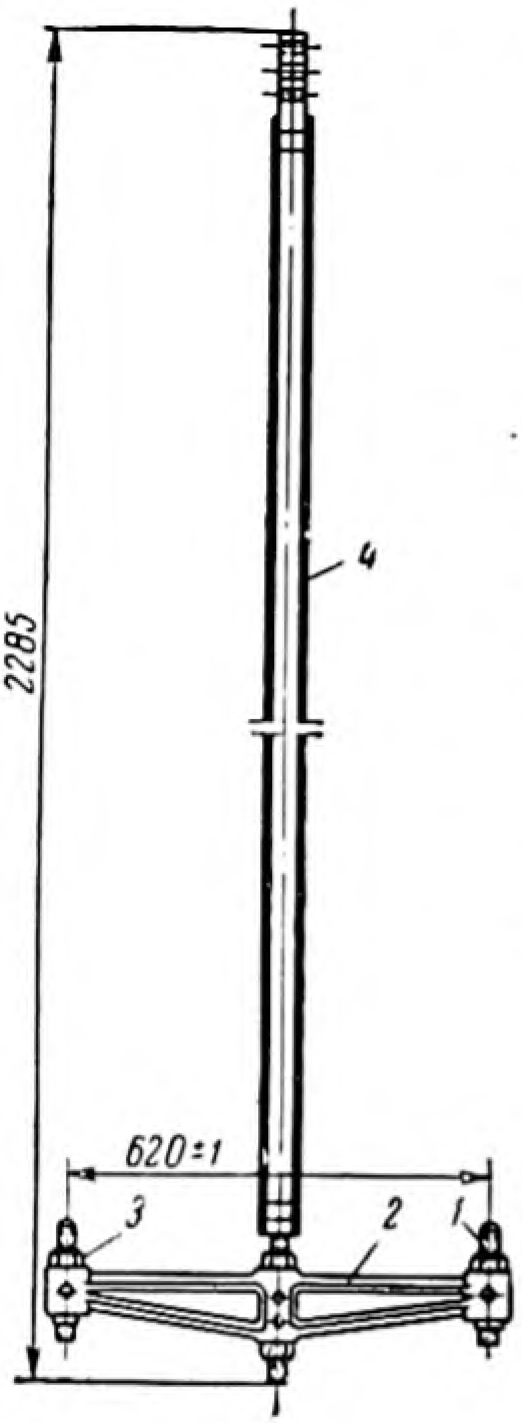


Fig. 220. Insulating lift rod and the moving contacts:
1—moving contact; 2—cross-arm; 3—nut; 4—insulating rod

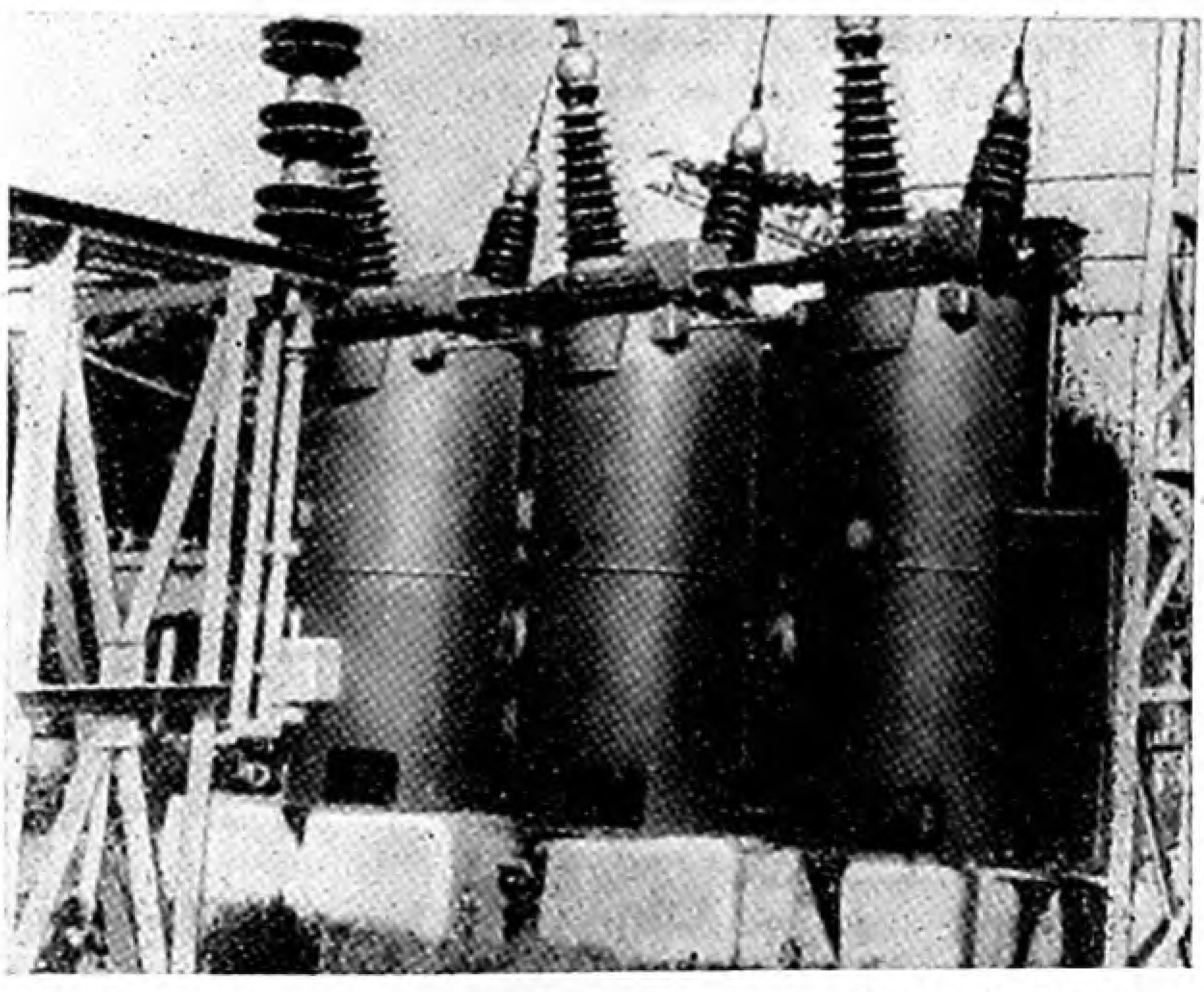


Fig. 221. View of an installed МКП-110 oil circuit breaker

33. Mounting of a BBH-110 Air-blast Circuit Breaker

The BBH-110 is an air-blast circuit breaker of the 110-kv class, intended for outdoor installation.

The main installation dimensions of this circuit breaker are given in Fig. 222; Fig. 223 shows a cross section through one of its phases. This circuit breaker weighs 7,090 kg.

BBH-110 circuit breakers are shipped assembled, with each phase assembly packed in a wooden crate, the only exception being the arc interrupter units, which are shipped separately packed.

After the boxes and crates are unpacked, the circuit breaker is checked for broken porcelain and missing parts.

In the absence of damage and with all parts on hand, the circuit breaker may be lifted onto its foundation by a truck crane (Figs 224 and 225) and given a take-down inspection.

Take-down inspection before installation. With the aid of a crane, first the support column *4* (see Fig. 223) is dismantled, taking care not to injure the porcelain air pipes *5* and *6*. After unscrewing the studs, the air pipes are pulled out and inspected for possible damage.

Following this, the truck-mounted control cabinet *3* is inspected, for which purpose the front, back and top cover plates are removed. Here the porcelain terminal blocks are checked for possible breakage and the reliability of the wiring connections.

The covers *21* are removed from the air receivers *1* and the latter are inspected on the inside. What traces of rust may be detected must be cleaned with a steel-wire brush, the receiver wiped with a clean dry rag, and the cleaned spots coated with a mixture of red lead paint and linseed oil.

The support insulator stack carrying the stationary contact or clip *18* is now inspected for broken porcelain and surface defects on the contact.

The arc interrupter unit (Fig. 226) is checked for broken porcelain, after which the nuts holding the unit together are unscrewed in order to inspect the internal parts (Fig. 227).

Next the front, back and side panels of the distributor cabinet (see Fig. 222) are removed and the contact thermometers, porcelain terminal blocks and the lead connections are checked.

Assembly of the circuit breaker. A very important point in the assembly of the circuit breaker is to make the joints as impervious to moisture as possible. The assembly procedure is described below.

The wheel-mounted assembly set up on the foundation should be levelled by means of a level, and the baseplate which is to receive the support insulator and the seat of the main blast valve *2* should be cleaned of dirt and wiped with a clean rag.

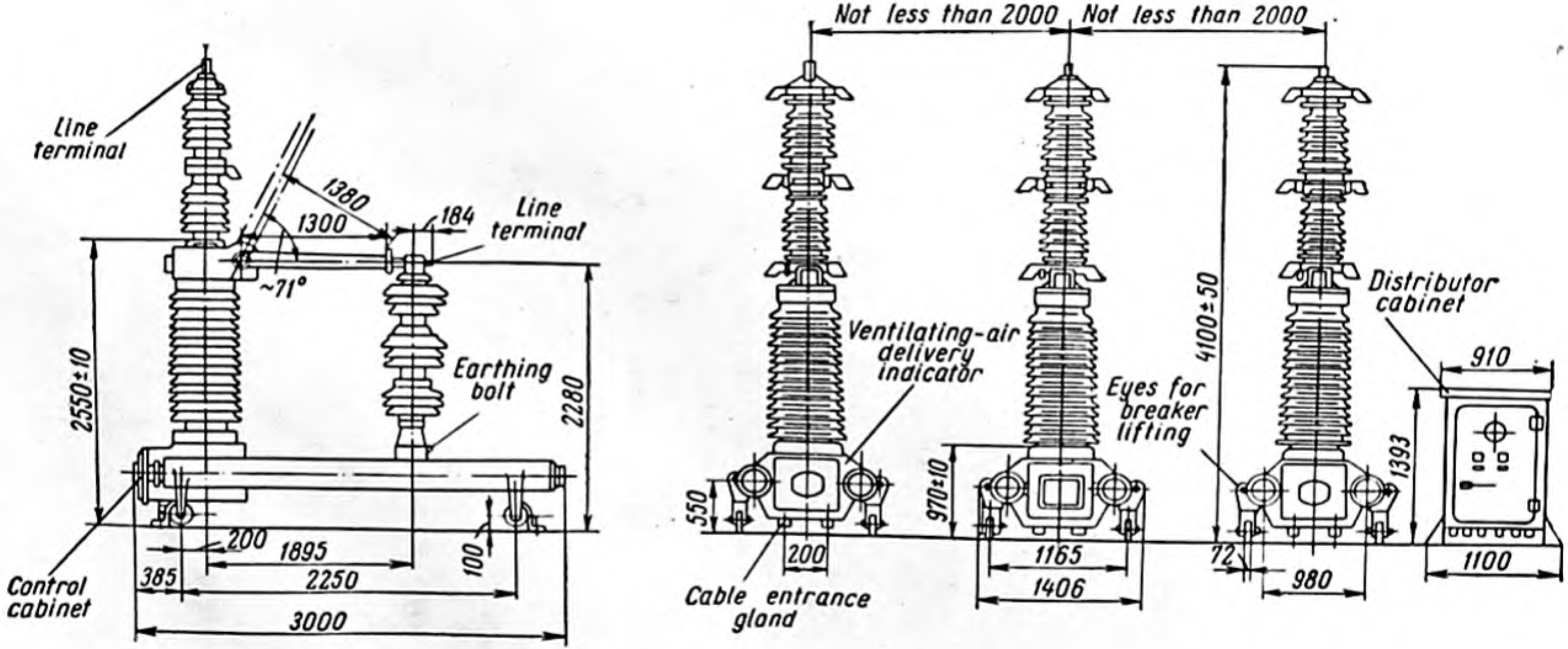


Fig. 222. **Installation drawing of a BBH-110 air-blast circuit breaker**

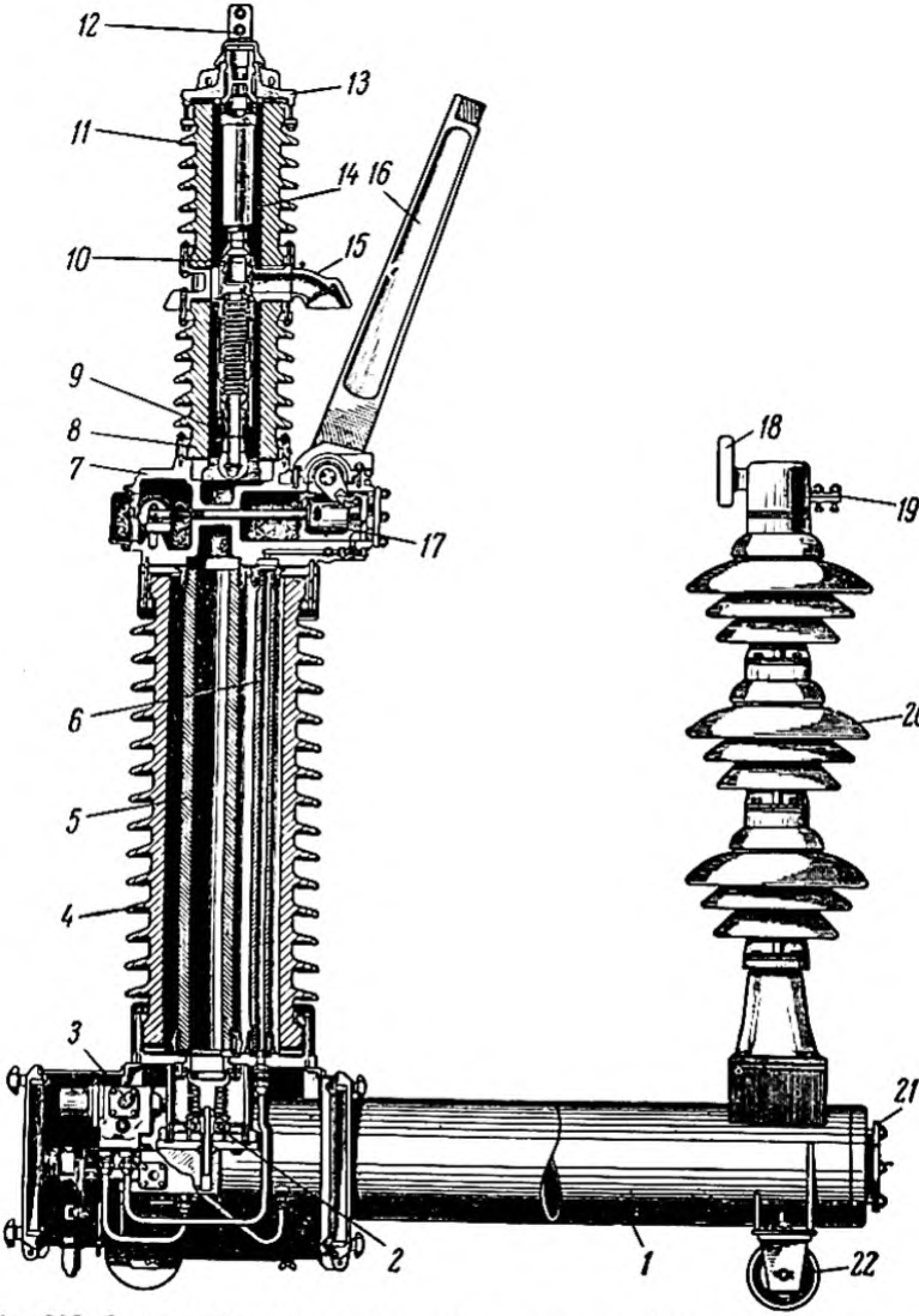


Fig. 223. Cross section of one phase of a BBH-110 air-blast circuit breaker:
1—compressed-air receiver; 2—air-blast valve; 3—control cabinet; 4—support insulator;
5—opening air pipe; 6—closing air pipe; 7—support flange; 8—porcelain shell; 9—moving
contact; 10—stationary contact; 11—porcelain shell; 12—upper terminal; 13—interrupter
unit cover plate; 14—interrupter unit; 15—vent pipe; 16—isolator blade; 17—isolator op-
erating mechanism; 18—stationary contact of isolator; 19—lower terminal of circuit breaker;
20—stationary-contact insulator stack; 21—air-receiver cover; 22—truck wheel

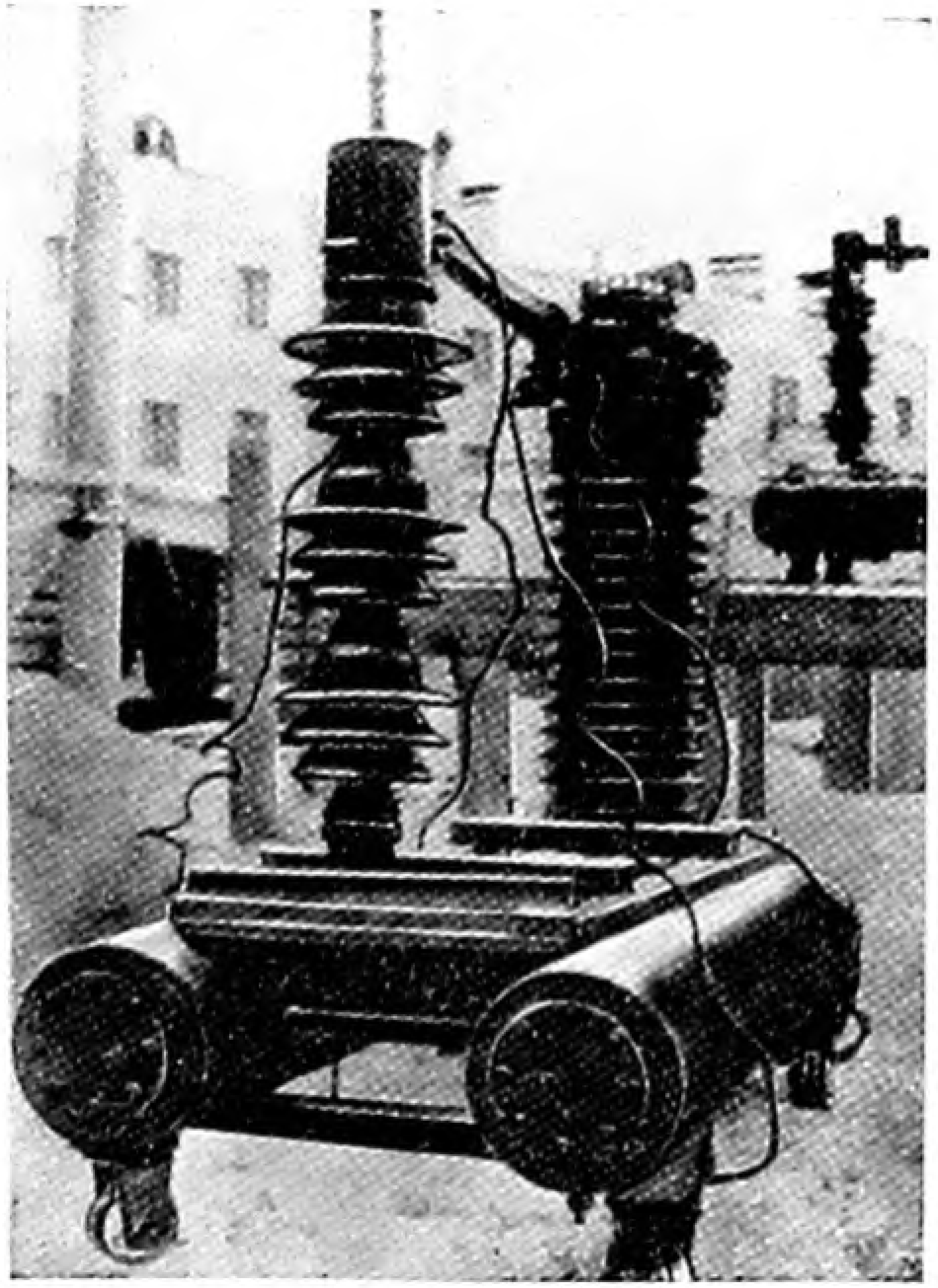


Fig. 224. Placing of slings on a BBH-110 air-blast circuit breaker

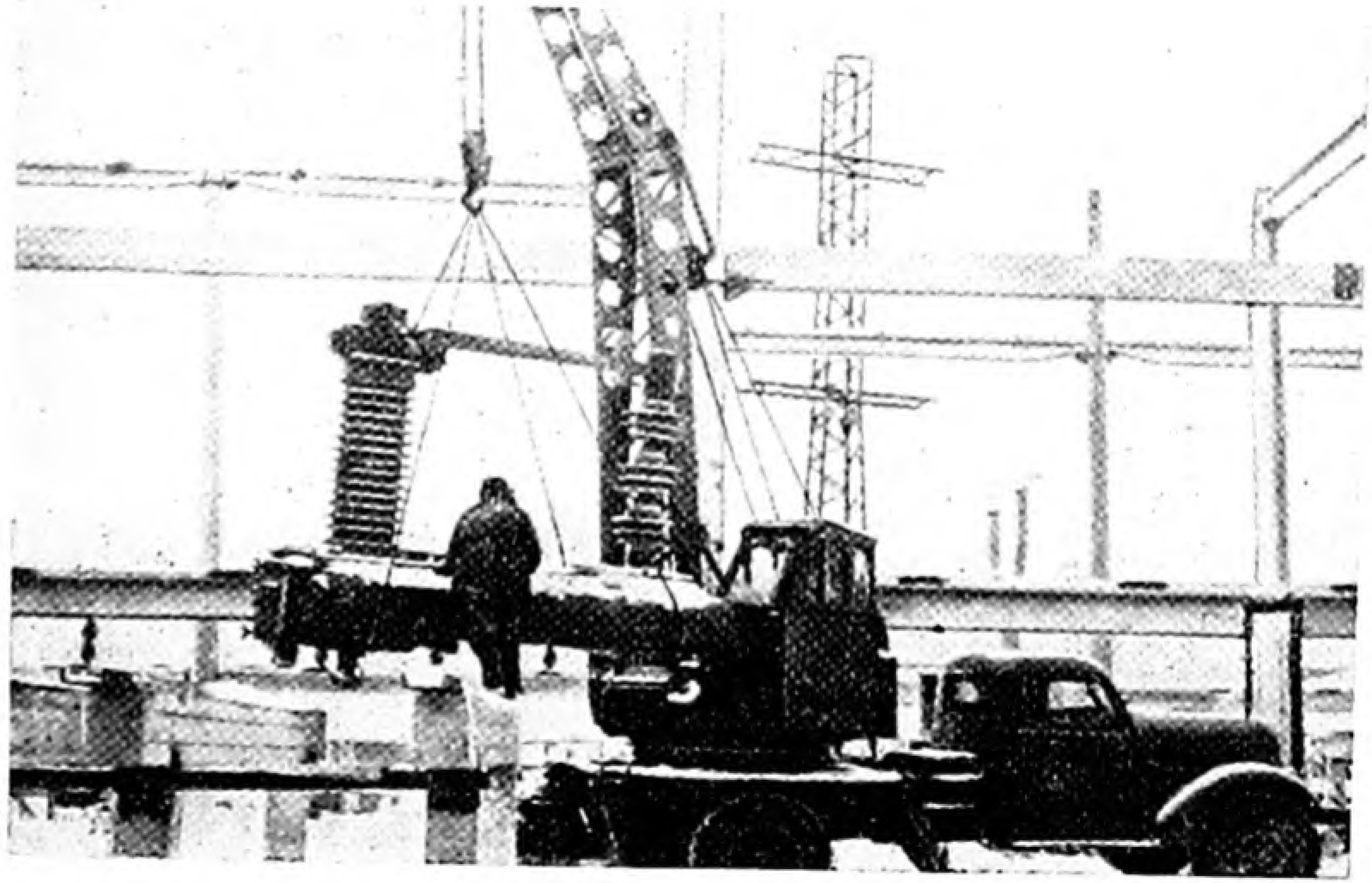


Fig. 225. Lifting a BBH-110 air-blast circuit breaker onto its foundation

Fig. 226. Preparing an interrupter unit for inspection

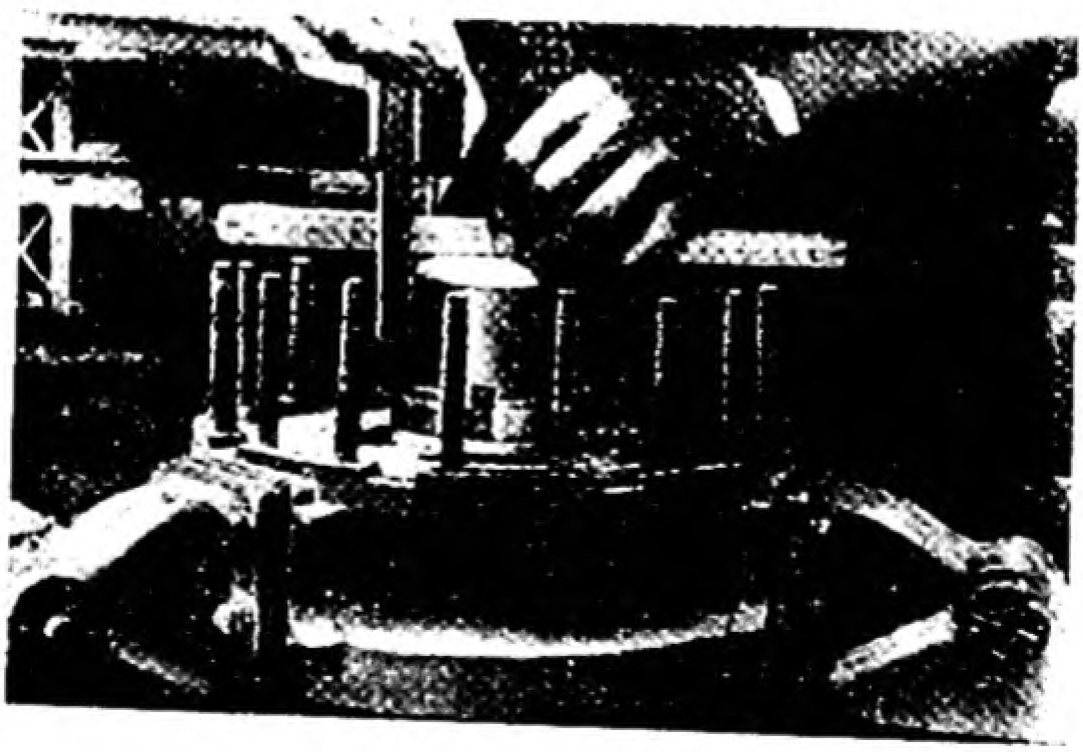


Fig. 227. Inspection of an interrupter unit

The opening air pipe *5* (see Fig. 223) is then installed, for which purpose twelve studs should be screwed into the baseplate, a gasket put on, a thrust sleeve set on it, and a rubber ring inserted in the sleeve. A flange is then placed on the ring, and the air pipe, wiped clean with a rag wetted with alcohol, is attached. The air pipe is secured by studs, nuts, and spring washers.

The closing air pipe *6* is installed in the same manner.

After the air pipes are put in place, a gasket and a spacer ring are placed on the truck baseplate, and studs wrapped in tow coated with a mixture of minium and drying oil are screwed in it.

As the spacer rings are carefully matched at the manufacturer's works to the height of the support column, care must be taken not to interchange them.

The support insulator *4* is then wiped with a clean rag moistened in petrol; packing rings and collars are slipped over the bottom shoulder of the insulator (the ends of the insulator should have their gaskets already cemented in place); the insulator is now tied with a hemp lifting rope under the upper skirt, lifted with a crane, and put into position on the baseplate.

When the support insulator is thus handled, it should be held in a vertical position, or the porcelain air pipes may be damaged. When the insulator is being lowered, a worker should stand on the breaker truck to ensure that the load is lowered plumb.

After the support insulator is placed on the baseplate, it must be secured with extreme care, as the slightest misalignment may lead to breakage of the insulator. For this reason, the nuts on the fixing bolts are first run down by hand and then tightened with a spanner, giving each nut a quarter of a turn at a time.

Then an adapter plate (omitted in the sectional view) is mounted on top of the support insulator.

With the support insulator mounted as described, the operating mechanism *17* of the isolator blade is attached to the support insulator by means of rings, studs and nuts, taking as much care as in setting up the support insulator on the truck baseplate. The nuts securing the operating mechanism should be finally tightened after the isolator blade has been aligned with the stationary contact *18*.

For this purpose the stationary contact is unbolted and brought into alignment with the isolator blade until the blade enters the contact precisely in the centre. After this, the stationary contact and the isolator operating mechanism may be finally secured in place.

Prior to mounting an interrupter unit, it should be taken apart, the porcelain surfaces and all the accessible parts should be wiped clean, and the rubbing surfaces of the contacts should be given a thin coat of special grease (ЦИАТИМ-201 or ГОИ-64). After this the units may be re-assembled.

The re-assembled units are set up on the support insulator and secured in place with bolts, taking care not to damage the porcelain.

The interrupter units should be so mounted that the vent ports are at right angles to the axis of the isolator blade and one of them on the middle flange looks in the direction of the blade.

After the interrupter units are mounted, the hoods are put on the flanges of the support insulator and the interrupter units.

The distributor cabinet is then mounted on a prepared foundation and secured to it with M12 bolts.

Checking of the breaker mechanism for operation. This check is carried out after the circuit breaker has been fully installed.

To check the operation of the operating mechanism, the spring which locks it is removed, and, by pushing the piston by hand, the isolator blade is raised to its uppermost position and is forcefully brought down into the stationary contact. The isolator blade should enter the contact jaws softly, so that the lower edge of the blade does not stick out of the jaws. This check should be repeated three or four times.

Now the oil dashpot (not shown in the figure) is filled with oil through the oil gauge opening on the side of the dashpot until it appears in the other (side) opening. The isolator blade is raised and lowered several times to force the air out of the dashpot cylinders, and more oil is added until the cylinders are completely filled. The oil-gauge hole may now be plugged, and another 150 to 200 grams of oil added through the upper hole, which must likewise be tightly plugged afterwards.

Operation of the interlock contacts is next checked. For this, the front cover of the control cabinet is removed and the moving system is shifted several times back and forth. This movement should take place without any binding or interference.

The mechanical system of the closing and opening electromagnets is tested for operation by hand and the strikers are checked to see that they are well locked by their nuts.

The covers *21* of the air receivers *1* are then put in place (see Fig. 223) and compressed air at about 15 atm (gauge) is piped into the circuit breaker, while the cover of the control cabinet should be left off.

All further work on an air-charged breaker must be performed by one man in order to avoid any accidents. This precaution is vital, for when several men partake in the work, it is not improbable that someone may find himself under the isolator blade when it is being closed, and suffer fatal injury.

Before the circuit breaker may be tested, the interlock contacts should be checked to determine that they indicate the position of

8*

the isolator blade properly. When the isolator is closed, the actuating mechanism of the interlock contacts should be positioned so that its lever and spring faces the man doing the checking.

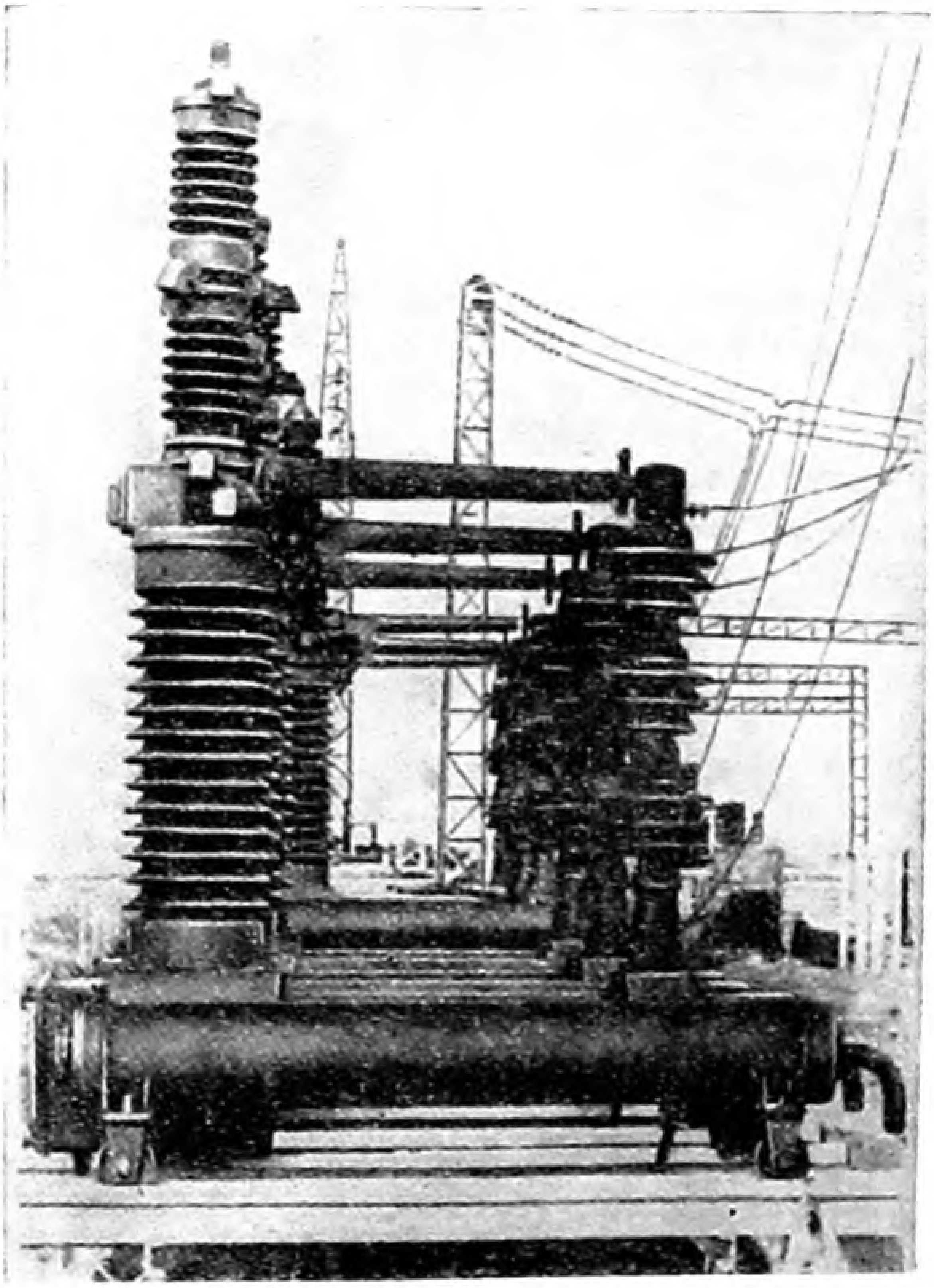


Fig. 228. General view of installed BBH-110 air-blast circuit breakers

A general view of BBH-110 breakers installed in an outdoor substation is given in Fig. 228.

Problem. Write up an operation sequence for mounting a BBH-110 breaker on a concrete foundation according to Figs 224, 225

34. Mounting of TΦH Instrument Current Transformers

Outdoor substations employ TΦH current transformers. The letters in the type designation indicate: "porcelain-insulated", for outdoor installation.

The mounting dimensions of these current transformers are given in Table 23 and Fig. 229.

Table 23

Principal Dimensions and Weight of Outdoor Current Transformers

Type designation	Rated voltage, kv	Dimension, mm (Fig. 229)									Weight, kg	
		A	B	C	D	E	l	F	G	H	Total	oil
ТФН and ТФНУ	10	880	480	440	480	440	705	—	—	145	220	35
ТФН and ТФНУ	35	1,085	534	498	520	488	890	—	—	300	270	45
ТФН	110	2,000	850	655	920	790	1,770	200	72	950	700	200

These current transformers are shipped in wooden boxes fully assembled, but with their arcing horns detached and tied to the base.

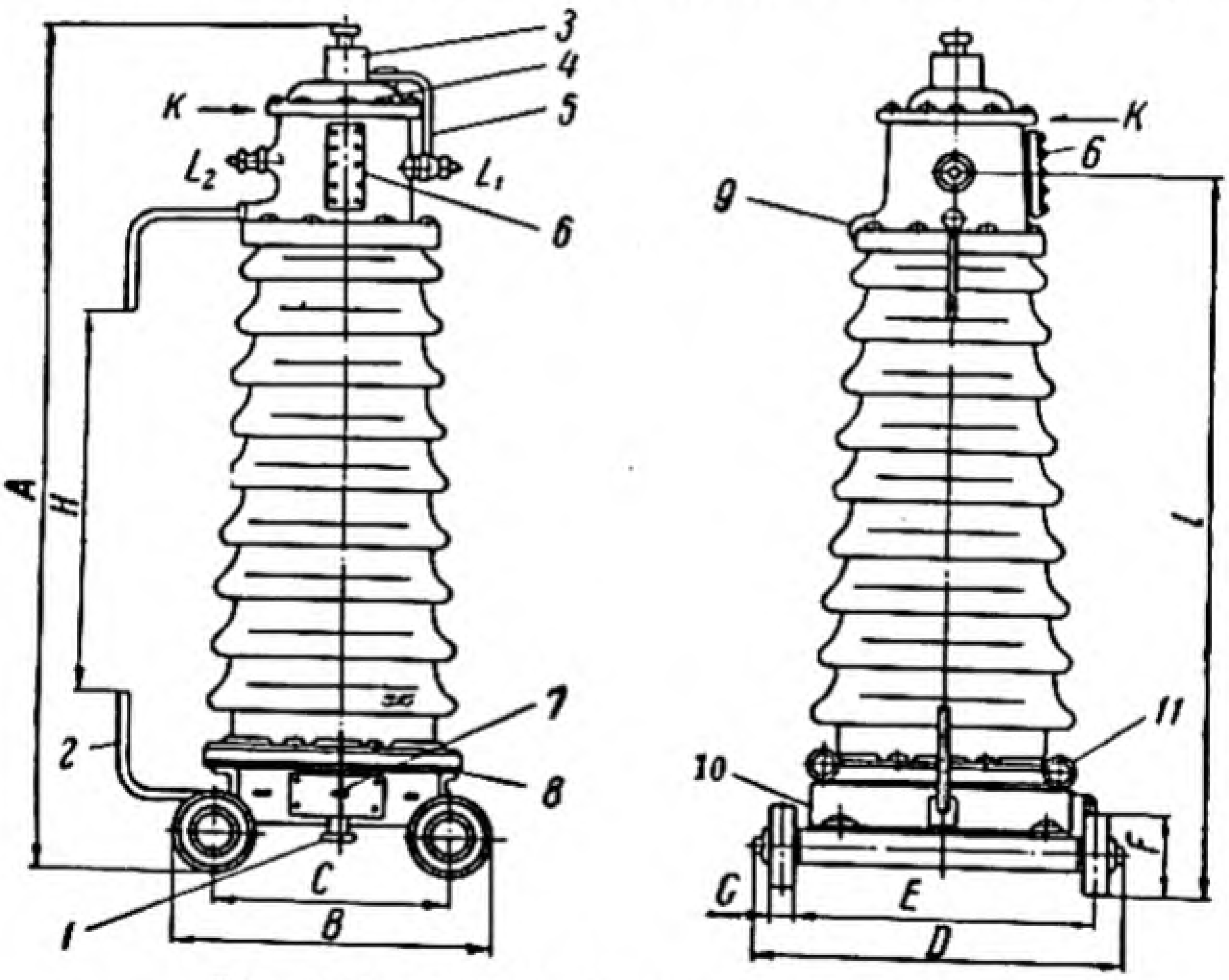


Fig. 229. ТФН-110 current transformer:
1—cable box; 2—arcing horn; 3—surge diverter; 4—cover; 5—busbar terminal; 6—oil level gauge; 7—secondary-winding terminal box; 8—earthing bolt; 9—condensed-moisture drain plug; 10—oil drain fitting; 11—lifting ring

In transit the current transformer must stand upright to within 15 degrees.

Once on the site, the current transformer must be unpacked, wiped clean, first with rags moistened with petrol and then with a clean

dry cloth. At the same time it is examined for broken porcelain, missing parts and nameplate, and for oil level.

At an ambient temperature of +20°C the oil should be level with the red mark on the oil gauge. For other ambient temperatures, the oil level should be as advised in Table. 24.

Table 24

Oil Level for Different Ambient Temperatures

Ambient temperature °C	Distance, in mm, from point *K* (Fig. 229) on transformer head to oil level, for voltage ratings as below:		
	10 kv	35 kv	110 kv
0	125	135	200
−20	143	150	240
−40	165	165	280

If the oil gauge fails to show the oil level it must be checked as follows: remove the bar *5* connecting the surge diverter *3* with the terminal and unscrew the bolts which secure the cover *4*; remove the cover, and dip through one of the openings in the transformer head a brass stick of about 6 mm in diameter, wiped with a clean rag moistened in petrol. The length of dip-sticks and the depths to which they may be lowered in different current transformers are listed in Table 25.

Table 25

Lengths of Brass Dip-sticks and Depths to Which They May Be Lowered in Current Transformers of Different Voltage Rating

Type of current transformer	Rated voltage, kv	Length of dip-stick, mm	Depth to which dip-stick is lowered below point *K*, mm
ТФН and ТФНУ	10	375	125
ТФН and ТФНУ	35	475	170
ТФН and ТФНУ	110	600	500

In order to avoid dropping the dip-stick inside the current transformer, the dip-stick must be attached by a string to the transformer head. If, after removal, no traces of oil are found on the dip-stick, it is a sign of an impermissibly low oil level. The current transformer must then be dried out under vacuum, filled with oil and tested

under voltage. All the above operations must be performed under workshop conditions.

If the dip-stick shows traces of oil as much oil may be added as necessary to bring up the oil level to the required mark. Before

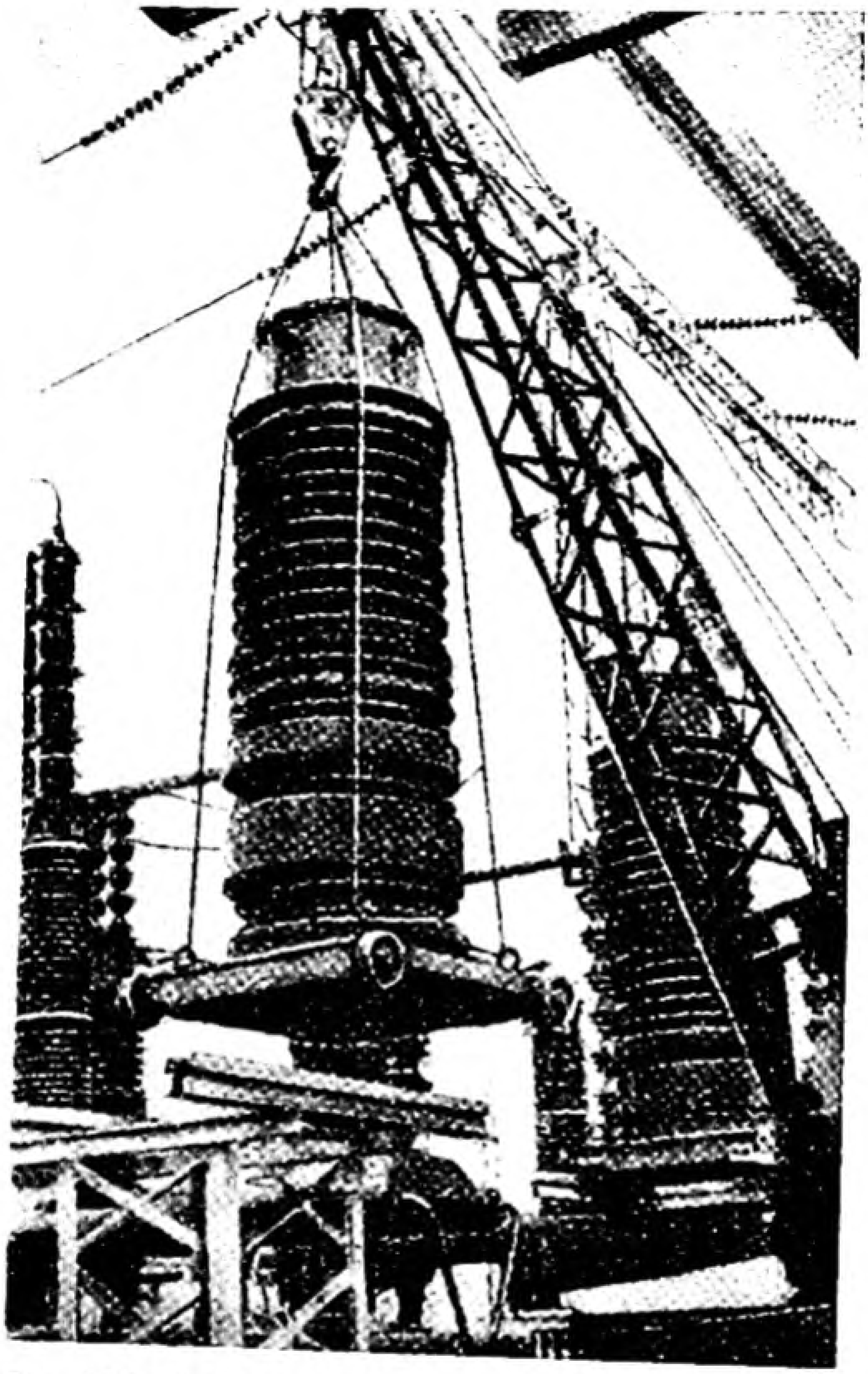


Fig. 230 Lifting of a current transformer on its metal support structure

performing this operation, the remaining oil and the condensate should be removed from the transformer head through the opening *9*.

The oil used for replenishment should be clean, dry, and unused, and have a breakdown voltage of not less than 35 kv and a congealing point of not lower than —45°C. During this operation all measures should be taken to shut moisture and dust out of the current transformer.

When the oil is brought up to the proper level, the cover *4* of the transformer head (complete with its gasket) and also the bar *5* may be put back in place. Following this, the gasketed joints are inspected to see that there is no oil leakage between the base and insulator, the insulator and head, the head and oil gauge cover, and also at the oil drain fitting *10*. If oil leakage is detected, the bolts at leaking joints should be very carefully tightened, giving each bolt not more than $^1/_{16}$ of a turn at a time.

Simultaneously, the primary terminals and their threads are examined. The nuts should be free to run on the threaded rods when turned by hand.

When a damaged insulator is discovered or when the leaking of the oil at a gasket cannot be stopped, the current transformer must be sent back to the factory for re-assembly.

A current transformer is lifted into its permanent position by a truck crane (Fig. 230). The wire-rope slings are attached to the four eye-bolts on the base. It is good practice to wrap hemp rope 40 to 50 mm in diameter around the upper fins of the insulator to avoid any damage to the porcelain by the slings.

In most cases ТФН current transformers are installed on metal or reinforced concrete supports.

Current transformers for 10 to 35 kv are fixed to their supports by means of M18 to M20 bolts. Transformers for 110 kv and higher are wheel-mounted and held in place by limit stops.

The arcing horns removed for transportation are then put back in place. The base of the current transformer must be earthed. For this purpose, the earthing lead bus is fastened to the bolt marked "З" ("З" for "earth").

Before a current transformer may be connected to the buses or cables, all its contacts must be cleaned of oxide and dirt.

A general view of ТФН-110 instrument current transformers mounted in a 110-kv outdoor substation may be seen in Fig. 231.

Problem. Write up the sequence of operations for mounting three ТФН-110 transformers in a substation as shown in Fig. 231.

35. Mounting of НОМ-35 and НКФ-110 Instrument Voltage Transformers

Voltage transformers НОМ-35 (single-phase 35-kv type) and НКФ-110 (110-kv, porcelain-insulated, cascaded type) are designed for use in outdoor substations with the corresponding working voltages.

The installation dimensions of these voltage transformers are given in Figs 232 and 233. The НОМ-35 voltage transformer weighs

248 kg, including 75 kg of oil. The НКФ-110 voltage transformer weighs 315 kg.

Prior to mounting in an outdoor substation, voltage transformers should be inspected externally and internally, for which purpose their core and winding assemblies are lifted out. The procedure

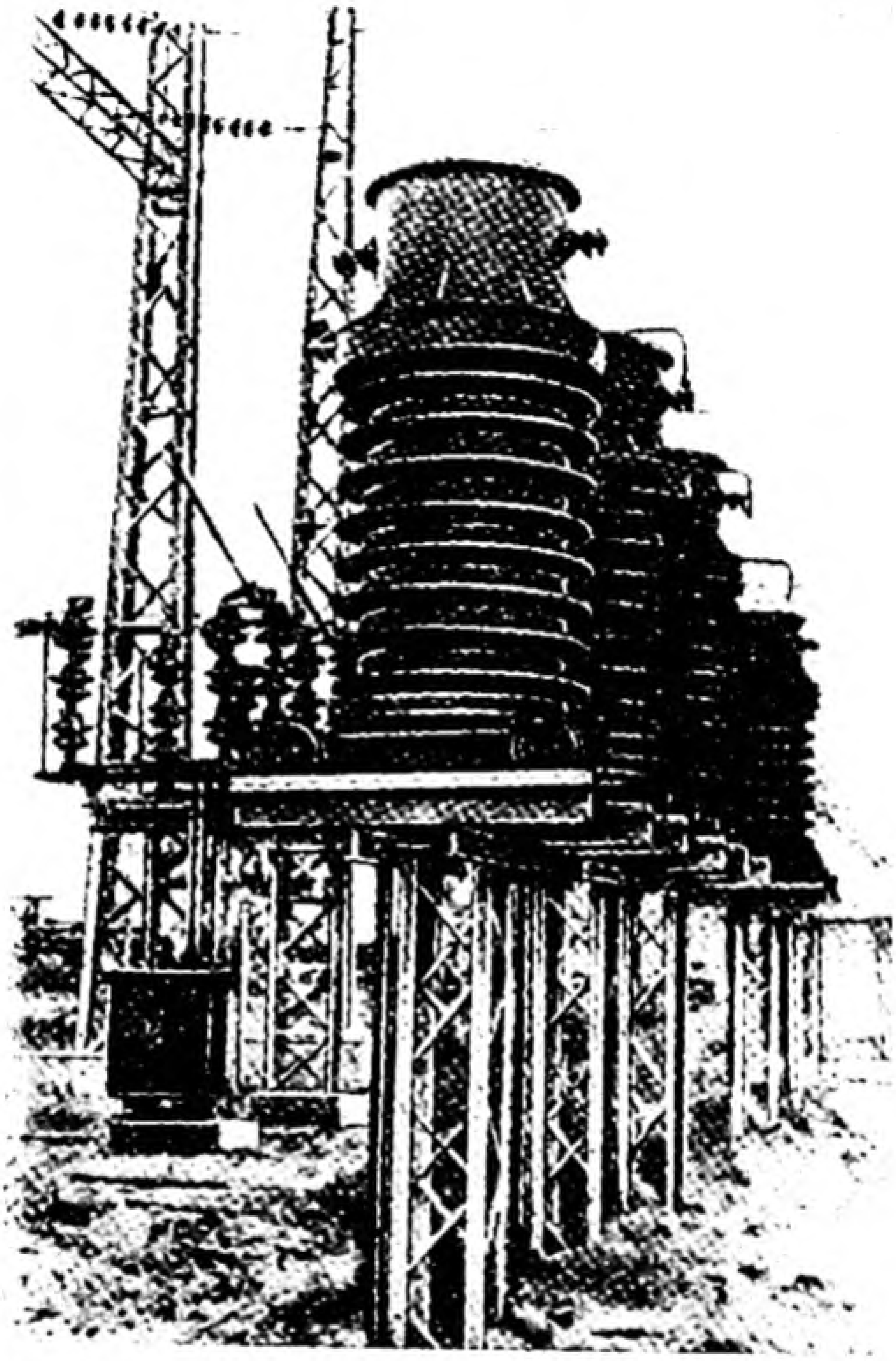


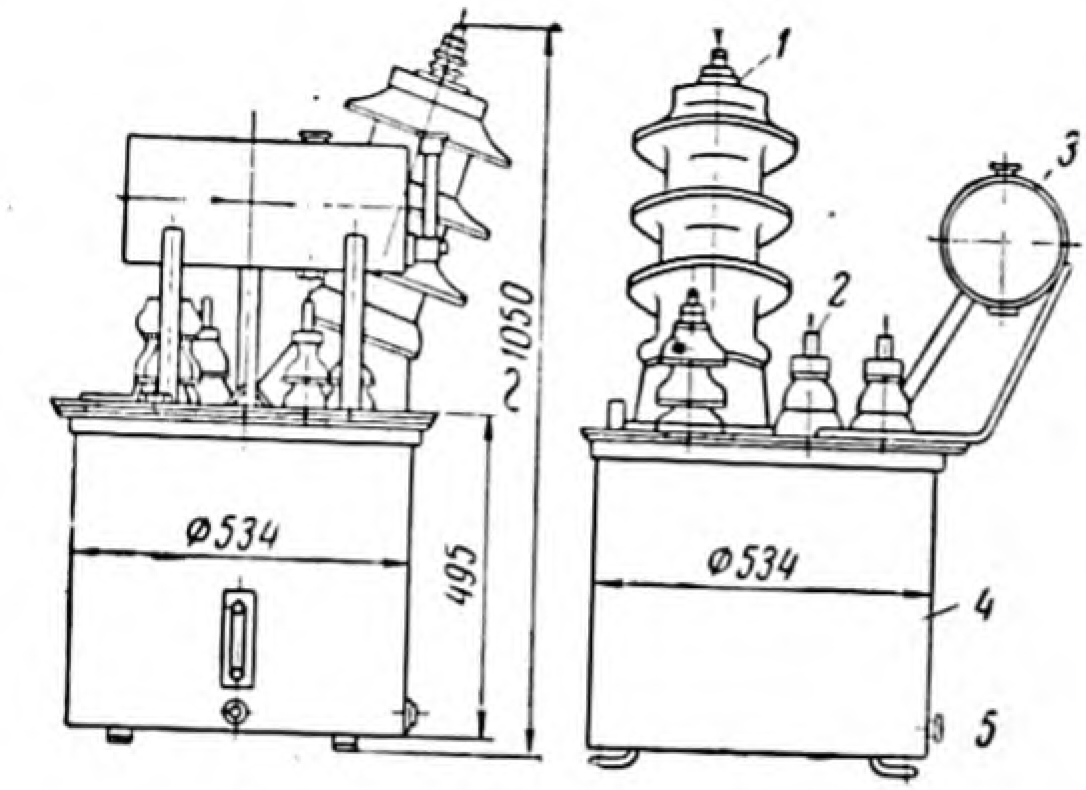
Fig. 231. A series of ТФН-110 current transformers installed on metal support structures

of the electrical tests is, in the main, the same as for indoor voltage transformers (see Sec. 18).

НОМ-35 voltage transformers are mounted on metal or reinforced concrete supports and secured to them by M16 bolts. НКФ-110 voltage transformers are mounted on similar supports but use M20 bolts. They are lifted into position by a truck crane, using the

eye-bolts provided on the cover (or base) of the transformer, or the lifting hooks welded to the tank.

When voltage transformers are being moved about, they should be held upright to within 30 degrees from the vertical.



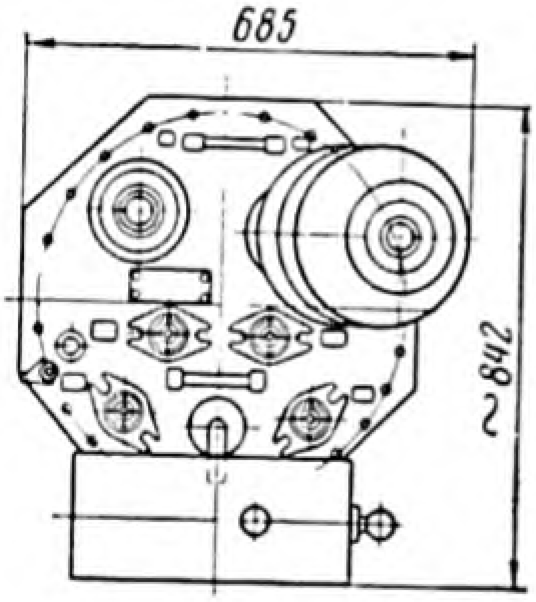


Fig. 232. НОМ-35 voltage transformer:

1—high-voltage terminal; *2*—low-voltage terminal; *3*—oil conservator; *4*—tank; *5*—oil drain cock

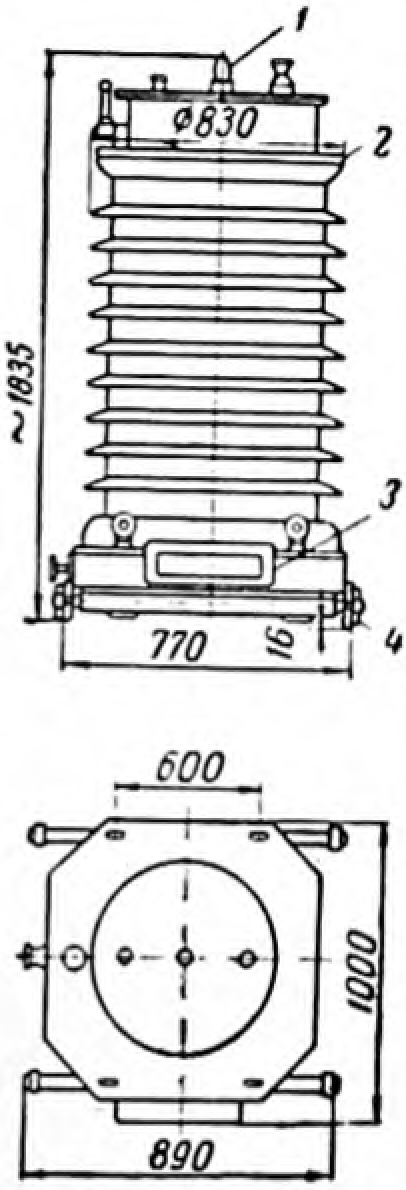


Fig. 233. НКФ-110 voltage transformer:

1—terminal for connection to high voltage; *2* — porcelain body; *3*—low-voltage winding terminals; *4*—rollers

Figs 234 and 235 show how НОМ-35 and НКФ-110 voltage transformers are mounted in outdoor substations.

36. Mounting of Reactors and Lightning Arresters

Mounting of reactors. Current practice is to install cast-in-concrete reactors in outdoor substations housed in brickwork or concrete kiosks where the installation procedure in no way differs from that carried out in indoor substations.

Mounting of lightning arresters. Outdoor substations for 35 to 110 kv employ РВП-35 valve-type substation lightning arresters, and РВС-110 valve-type main station lightning arresters. Their

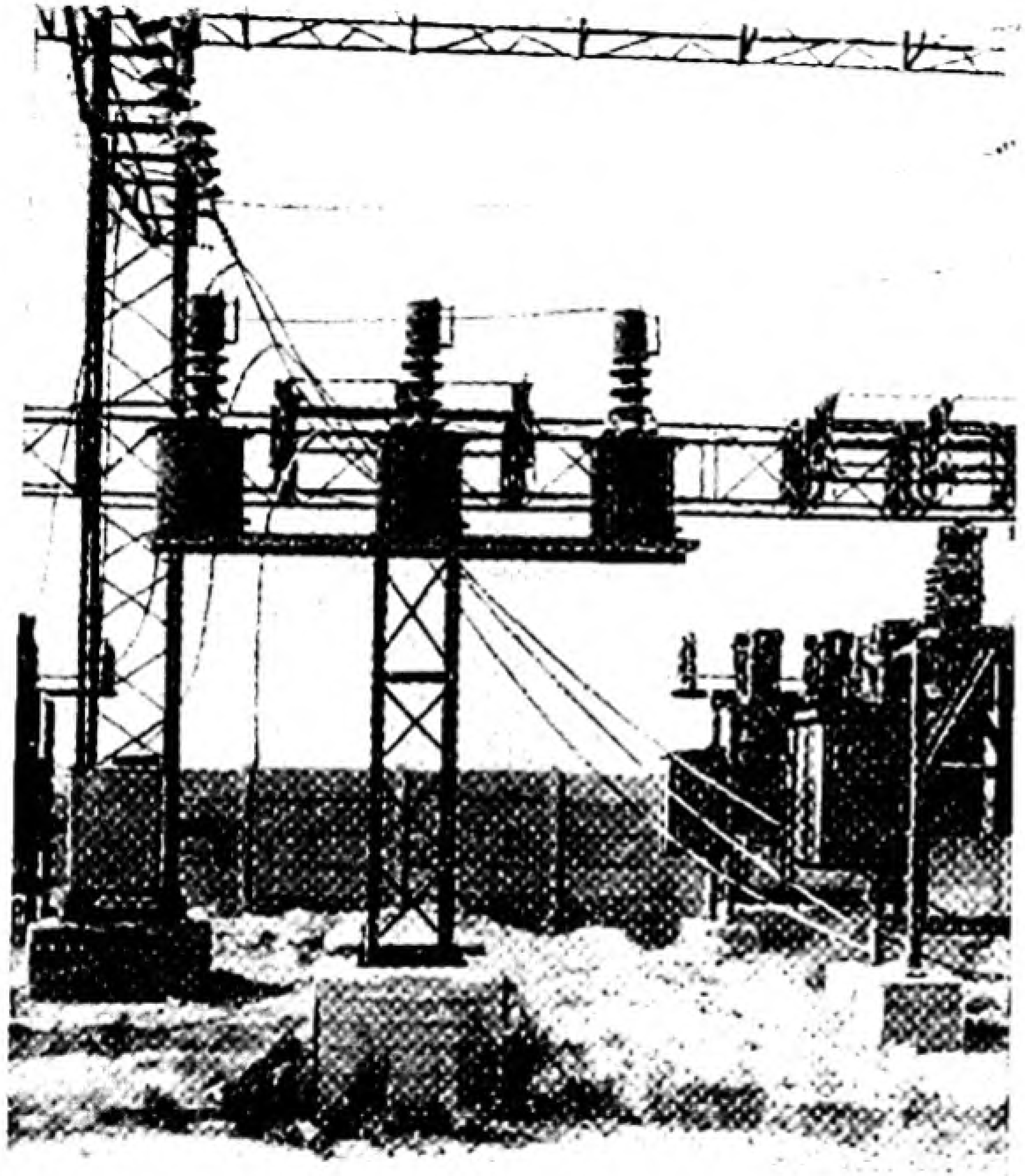


Fig. 234. НОМ-35 voltage transformers installed on a metal support structure in an outdoor substation

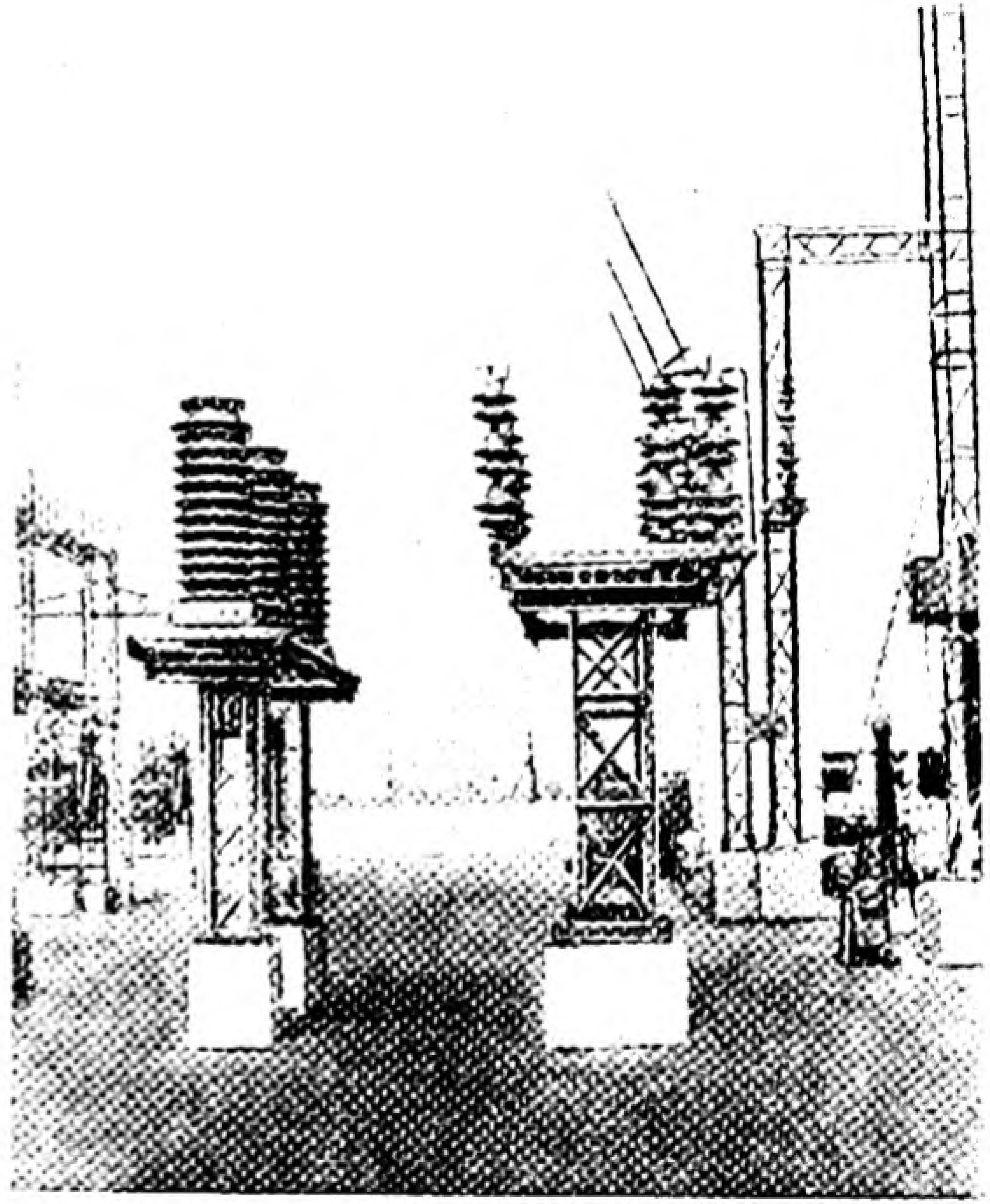


Fig 235 НКФ-110 voltage transformers installed on a metal support structure in an outdoor substation

installation dimensions are given in Figs 236 and 237. The РВП-35 lightning arrester weighs 76 kg, and the PBC-110 lightning arrester, 230 kg.

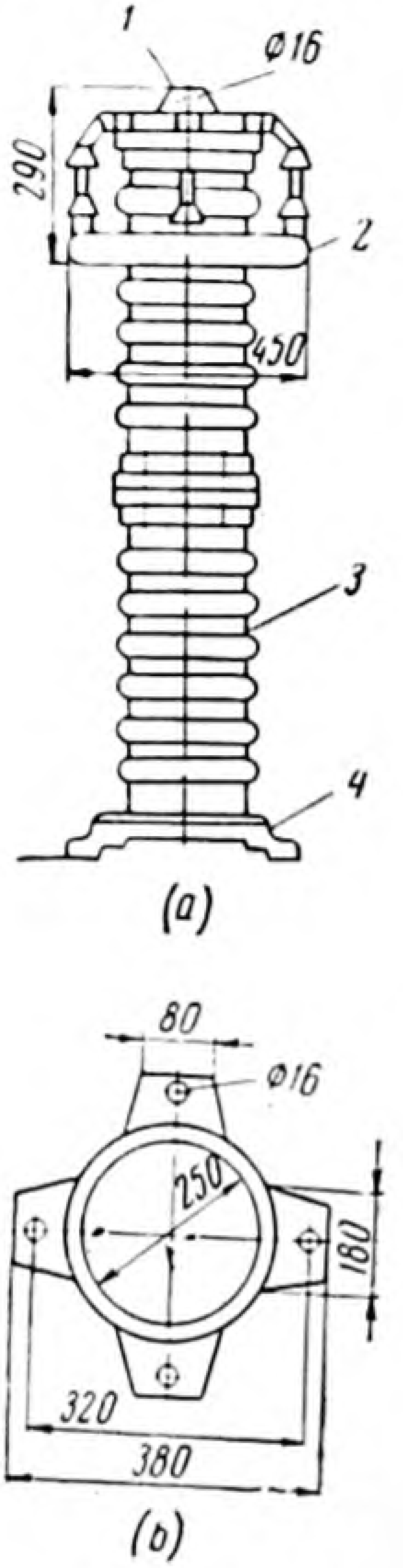


Fig. 236. РВП-35 valve-type lightning arrester:

a—general view: *1*—terminal for connection of phase conductor; *2*—shielding ring; *3*—porcelain shell; *4*—cast base of arrester; *b*—view of base

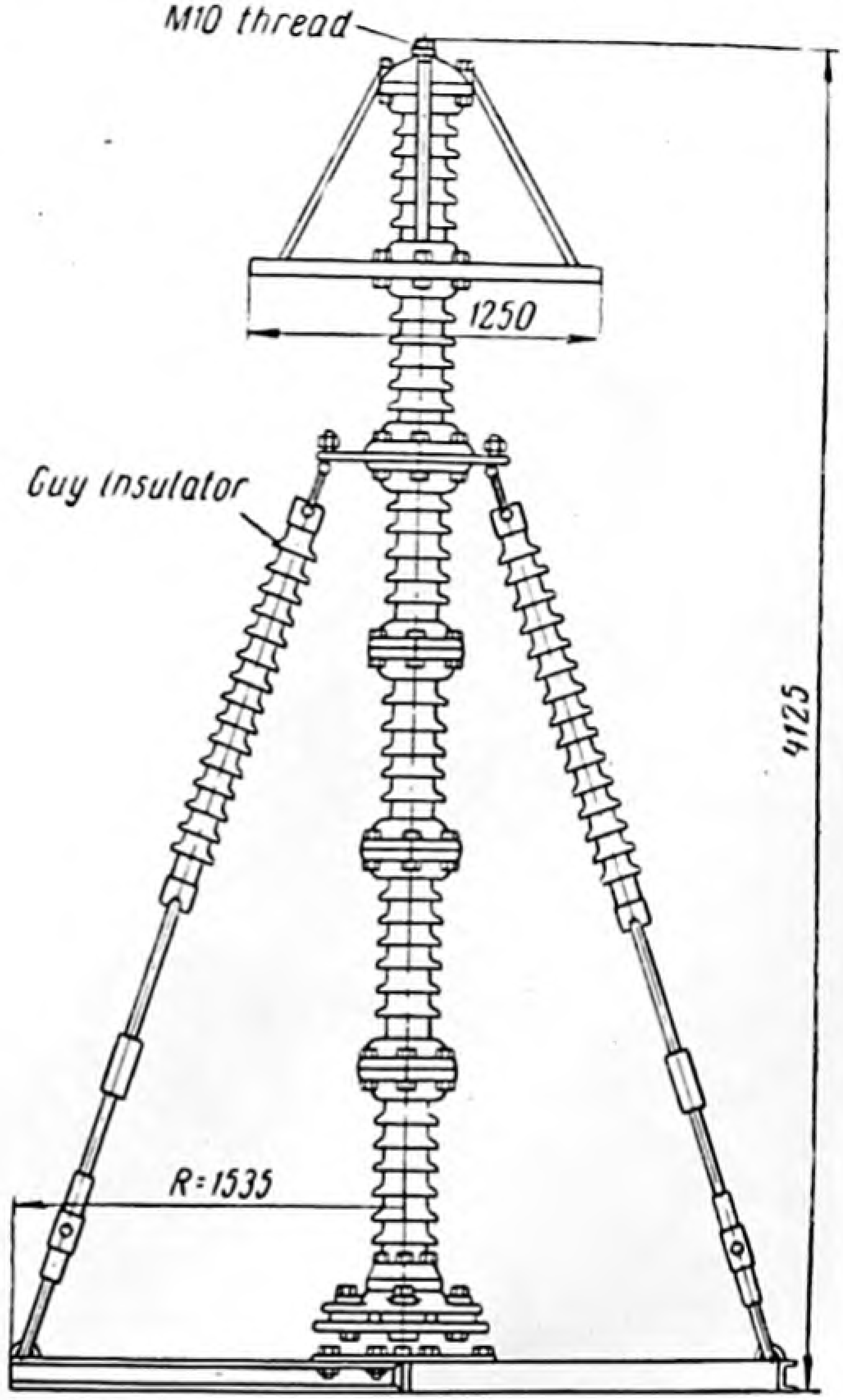


Fig. 237. PBC valve-type lightning arrester

Initial inspection for these lightning arresters is practically the same as for indoor substation lightning arresters (see Sec. 21).

Both PBC-110 and РВП-35 lightning arresters are mounted in fundamentally the same way.

To begin with, the support is plumbed and levelled. Then the arrester elements are matched according to their markings on the flanges (*1-1*, *2-2*, *3-3*), their contact surfaces are cleaned, the elements are assembled into stacks which are then checked for verticality, and any

misalignment is remedied by inserting steel shims. The joints at the flanges are given a coating of bakelite or glyptal varnish.

When setting up a lightning arrester, extreme care must be exercised in tightening the bolts on the joints between the separate elements, giving each nut no more than a quarter of a turn at a time round the circle. Nonuniform tightening of the bolts may crack or break the porcelain.

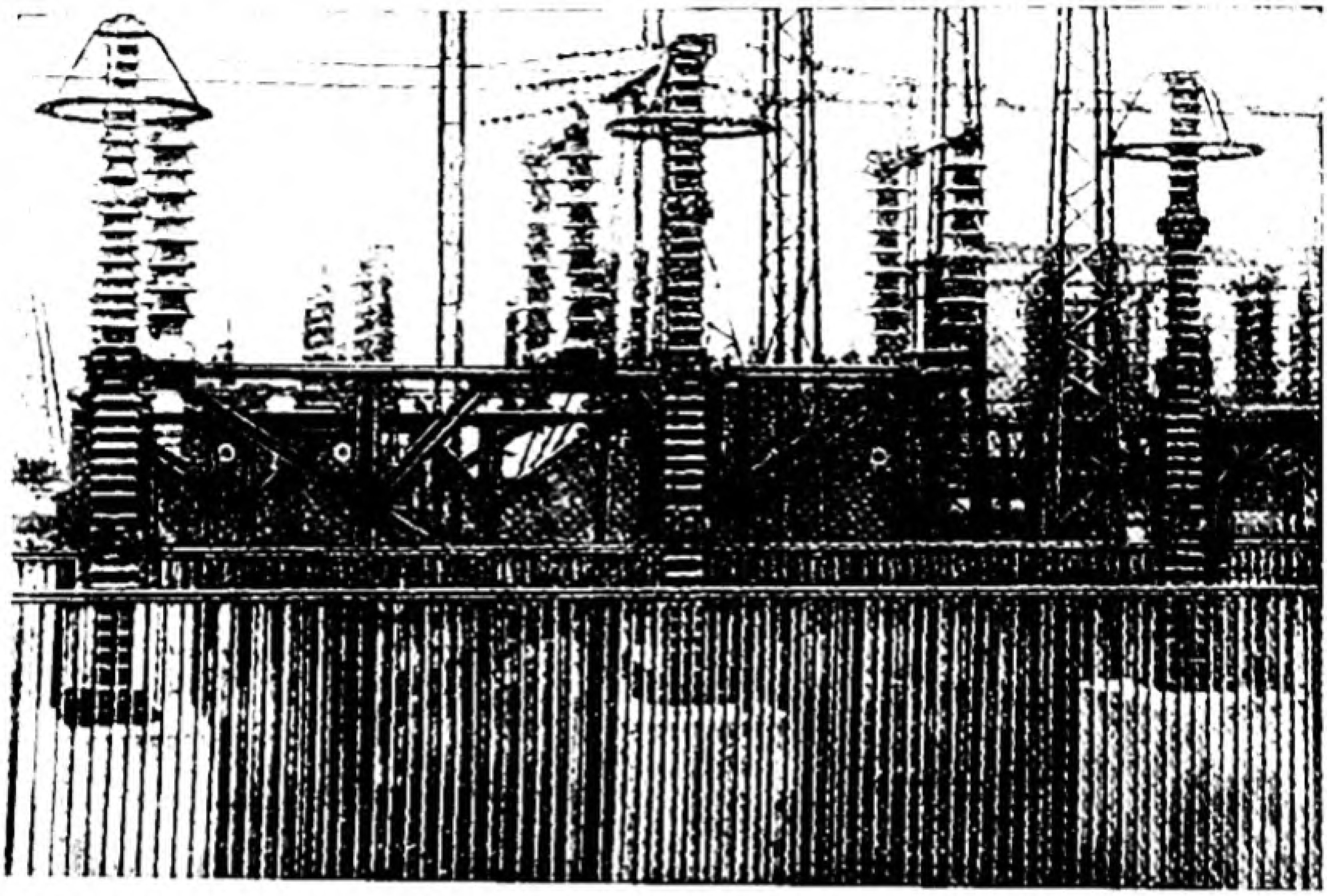


Fig. 238. General view of a lightning arrester bay in an outdoor 110-kv substation

The bolts should have spring washers to take up the stresses created by the tightening.

After a stack has been assembled, the joints are given another two or three coatings of moisture-proof varnish for air-tightness.

The earthing buses of each phase should be connected to the earthing system over the shortest possible route in order to keep their total resistance to a minimum and so as to prevent mechanical stresses from being set up in the arrester contacts.

A general view of a lightning arrester bay in an outdoor substation is shown in Fig. 238.

Problem. Write up an operation sequence card for mounting a station-type PBC-110 lightning arrester on a concrete foundation.

37. Installation of Outdoor Buses

The bus systems of outdoor switchgear are mainly made from aluminium, aluminium steel-cored, and, in some cases, steel cables carried by strings of suspension insulators.

Some of the data on these cables are listed in Table 26 below.

Table 26

Bare Aluminium and Steel-cored Aluminium Cables for Outdoor Substations

Nominal cross-sectional area of aluminium, sq mm	Wires per cable		Weight of cable, kg per km	Normal shipping length, m
	Aluminium	Steel		
Aluminium, Grade A				
50	7	—	135	3,500
70	7	—	188	2,500
95	7	—	256	1,750
120	19	—	323	1,500
150	19	—	401	1,250
185	19	—	496	1,000
Steel-cored aluminium, Grade AC				
50	6	7	193	3,000
70	6	7	296	2,000
95	28	7	386	1,400
120	28	7	504	1,400
150	28	7	623	1,000
185	28	7	781	800
240	28	7	995	1,000
300	28	7	1,258	800
Steel-cored aluminium, Grade ACY				
120	30	7	540	1,400
150	30	7	679	1,000
185	30	7	843	800
240	30	7	1,093	1,000
300	30	19	1,369	800

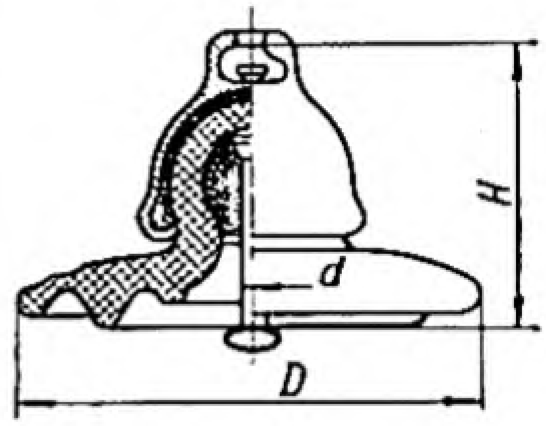
Note: The letters in the type designations of the cables stand for: *A* for "aluminium", *C*—"steel-cored", *Y*—"extra-strong".

The above types of cables are generally sold by weight.

The types, main dimensions and weights of suspension insulators used in this work, are given in Table 27.

Main Dimensions and Weight of Several Types of Suspension Insulators

Type of insulator	Main dimensions, mm			Unit weight, kg
	H	*D*	*d*	
П-3	150	245	14	4.8
П-4.5	170	270	16	6.7
П-6	180	300	20	8.5
П-8.5	203	320	22	11.8
П-11	215	350	24	14.3



Suspension insulators are assembled into strings to suit the working voltage of the installation. Thus, a string for 35 kv will consist of two to three units, and for 110 kv, of six to eight units.

Strings of insulators are strung with the aid of suitable links and clamps. An example of their use is shown in Fig. 239.

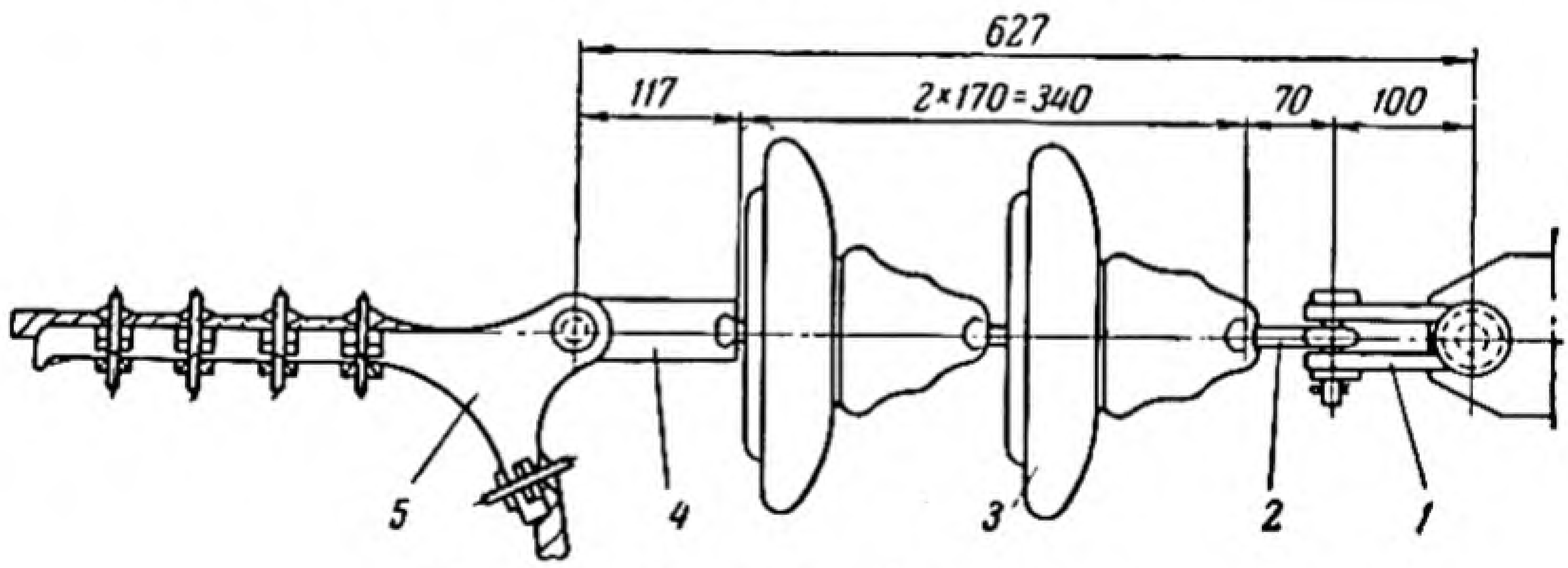


Fig. 239. Tension insulator string:
1—shackle for securing to tower cross-arm; 2—ball-eye fitting; 3—insulator; 4—socket-eye fitting; 5—bolted clamp fitting

Before a string of insulators is assembled, the insulators must be thoroughly inspected and cleaned. If the porcelain is found to be defective (have chipped spots, scratches on the glazing, cracks, unglazed spots), the insulator must be discarded.

Assembled strings of insulators are then laid out at the supports from which they are to be suspended.

Installation of a bus system consists in the following.

After suspension insulator strings are assembled and taken to their sites, the bus cable is run out, for which purpose the cable drum is lifted with screw jacks placed under a spindle passed through the drum. This can also be done on support horses. In some cases the cable may come in coils in which case the latter may be uncoiled on vertical-stand reels.

Cables should be cut to lengths which keep the number of splices to a minimum, as a splice is a weak point in a bus system.

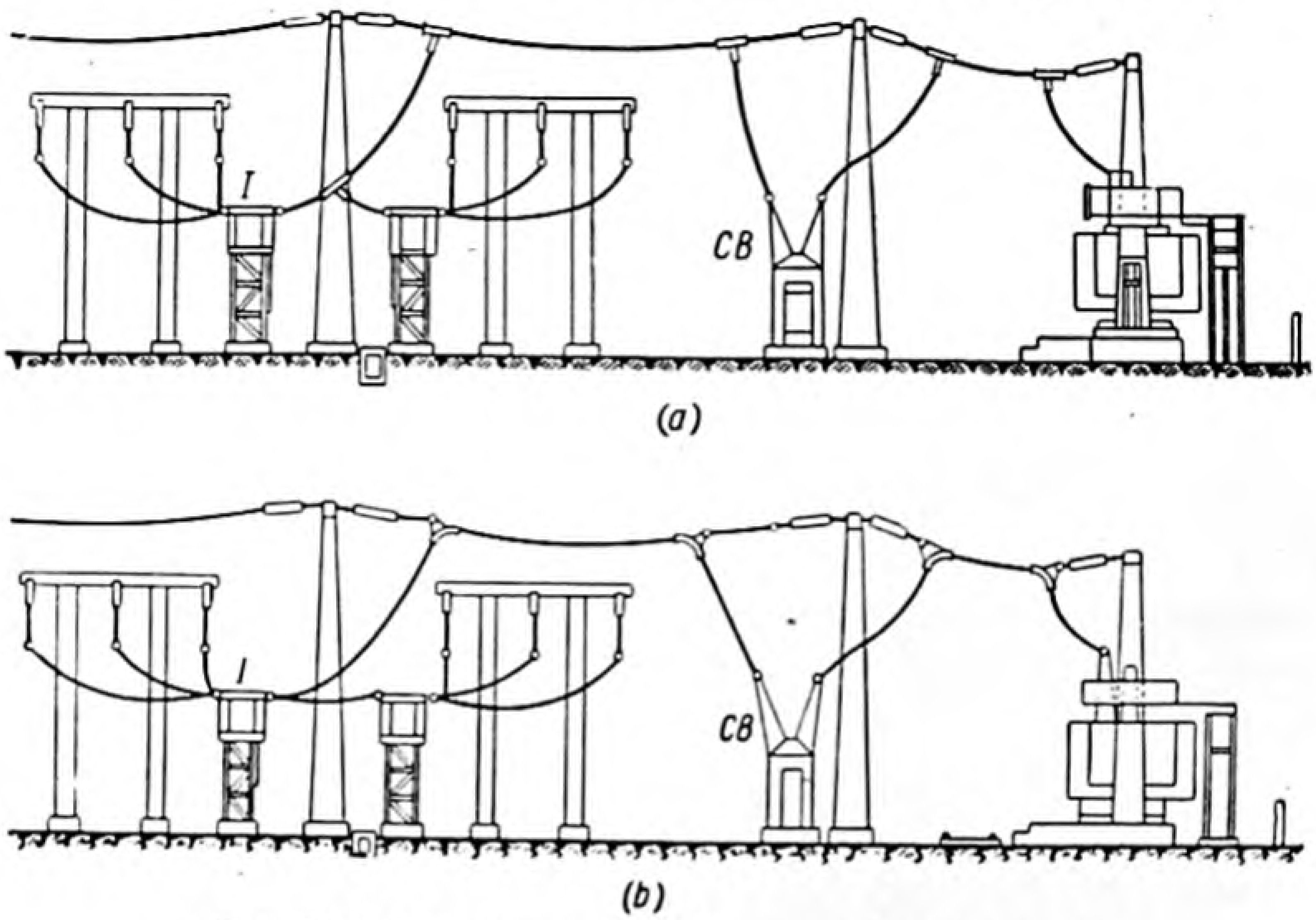


Fig. 240. Bus arrangement in an outdoor substation:
a—incorrect; *b*—correct

Fig. 240 gives examples of the correct and incorrect ways of connecting up a bus system. In Fig. 240*a* the run from the circuit breaker *CB* to the isolator *I* has five series-connected clamps (three for tees and two for the apparatus), while in Fig. 240*b*, there are only two apparatus clamps. The circuit breaker and the isolator in the latter case are connected by a single length of cable.

After running out, the end of the cable is secured in the clamp of the outer support. The lengths of the cable on either side of the clamp should be left in conformity with the erection drawings and with the scheme of connection adopted.

The cable end, at the point where it is to be fixed in the clamp, should first be served with a strip (1 mm by 30 mm) of the same metal as the outer strands of the cable. This precaution is necessary in order to avoid injury to the wires of the cable.

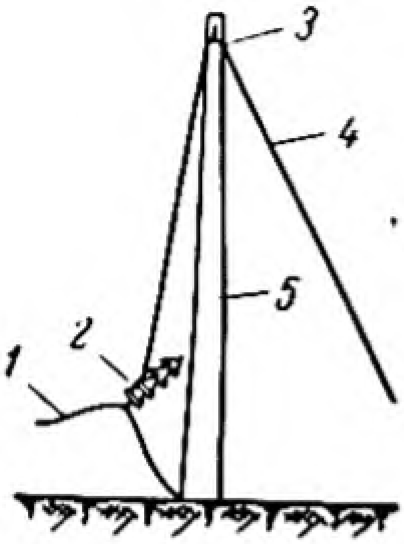


Fig. 241. **Lifting of an insulator string with conductor attached:**

1—conductor; 2—insulator string; 3—tackle block; 4—rope; 5—line support

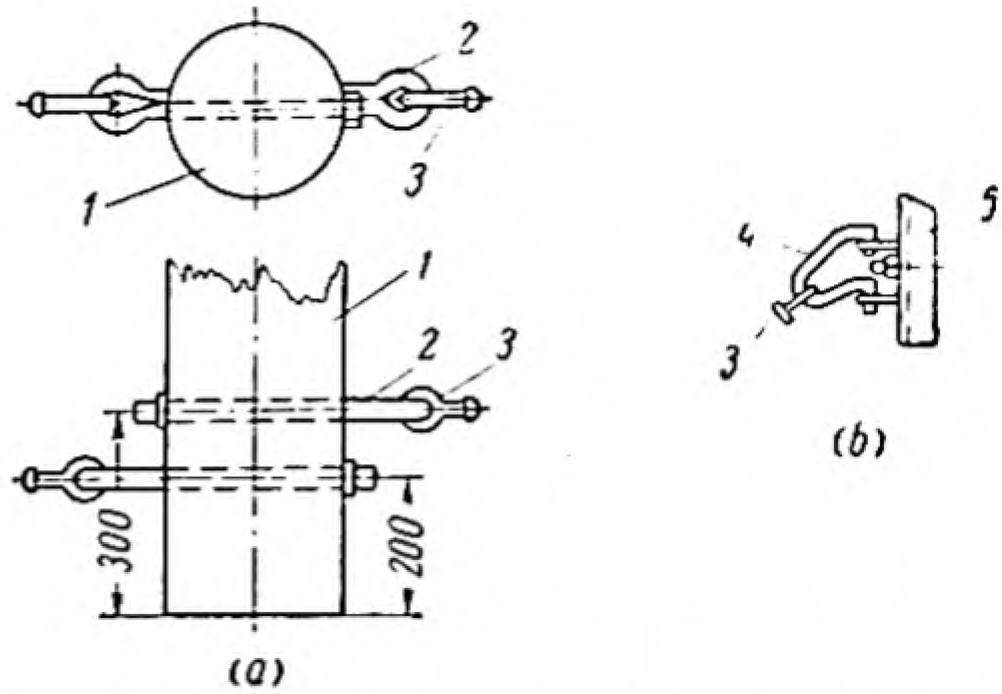


Fig. 242. **Securing of insulator string to a line support:**

a—to wood pole support; b—to metal tower support: 1—wooden cross-arm; 2—welded eye bolt; 3—shackle; 4—shaped bracket; 5—metal tower member

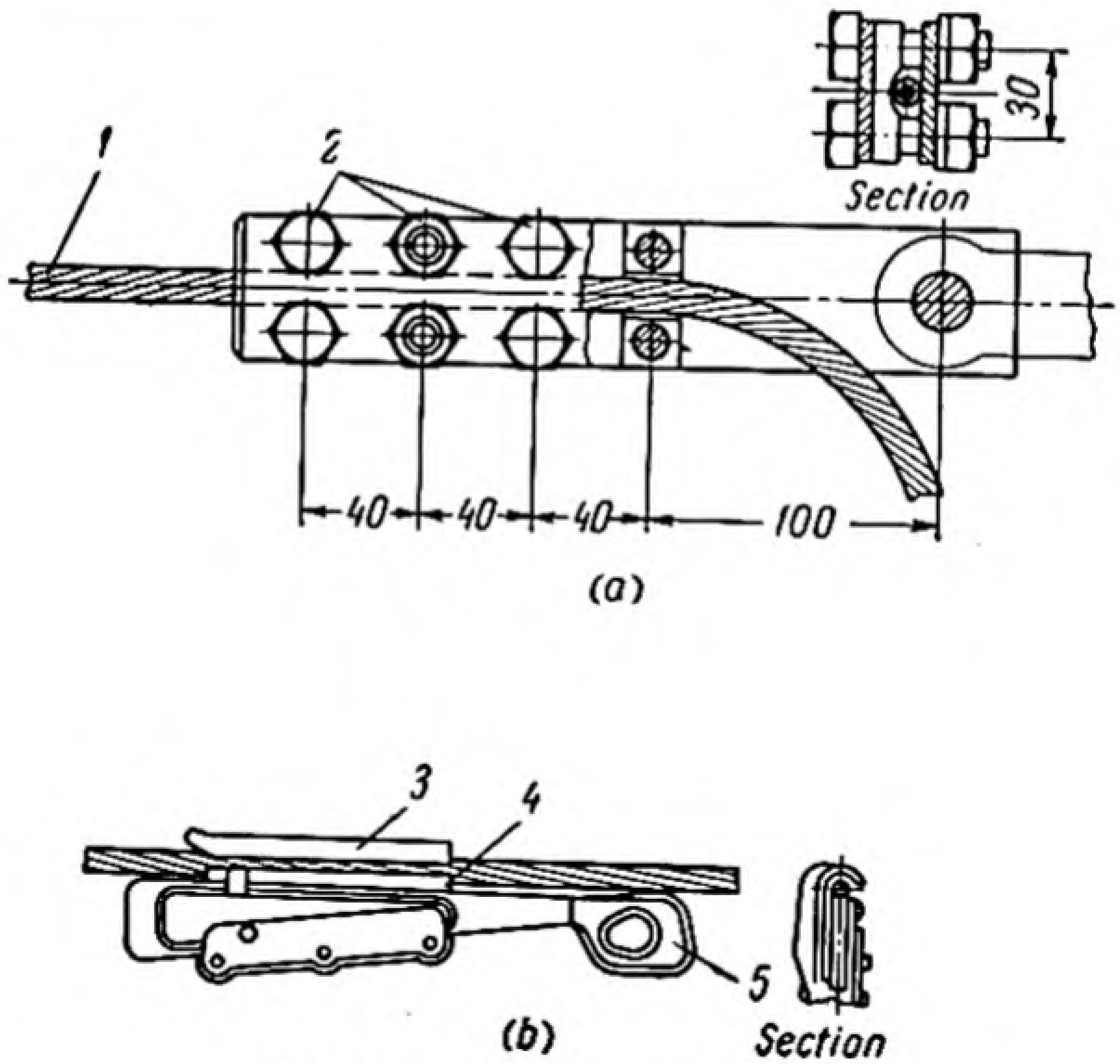


Fig. 243. **Stringing clamps:**

a—die-plate type; b—wedge-type: 1—conductor; 2—bolts; 3—body and cover plate; 4—under plate; 5—wedge

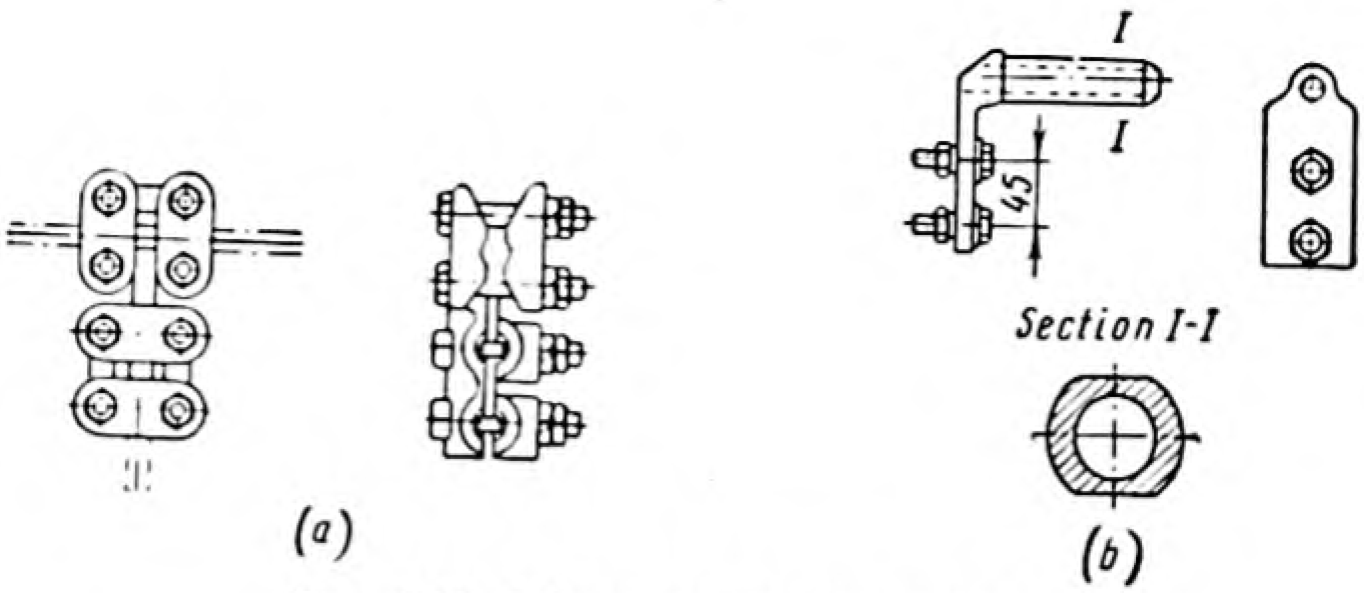


Fig. 244. Substation contact clamps:
a—bolted-type; *b*—compression-jointing type

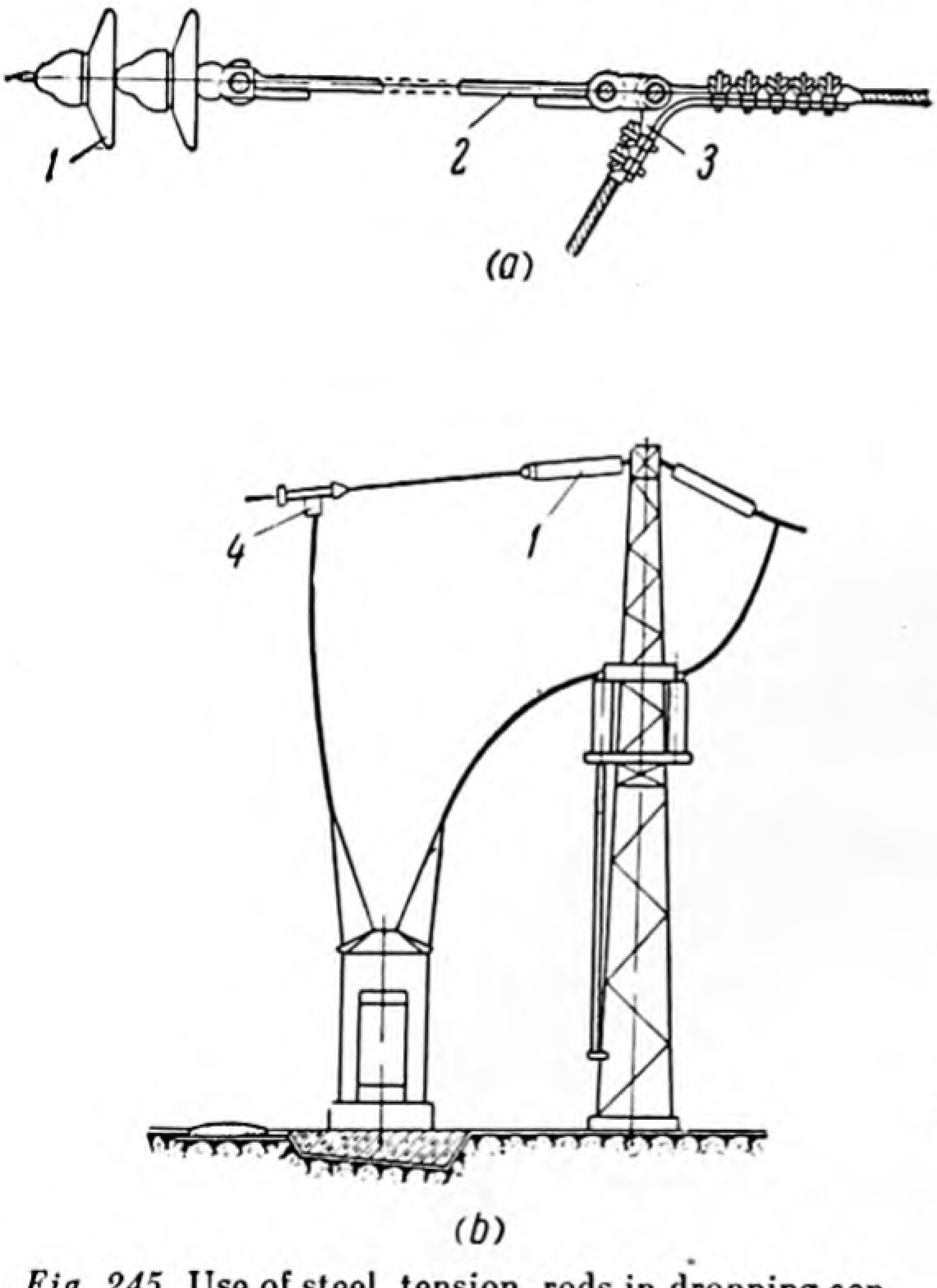


Fig. 245. Use of steel tension rods in dropping conductors for connection to apparatus:
a—connection of tension rod to an insulator string and a conductor clamp. *b*—a tee-off arrangement for connection to a unit of apparatus:
1—insulator string; *2*—steel rod; *3*—tension clamp; *4*—tee-off clamp

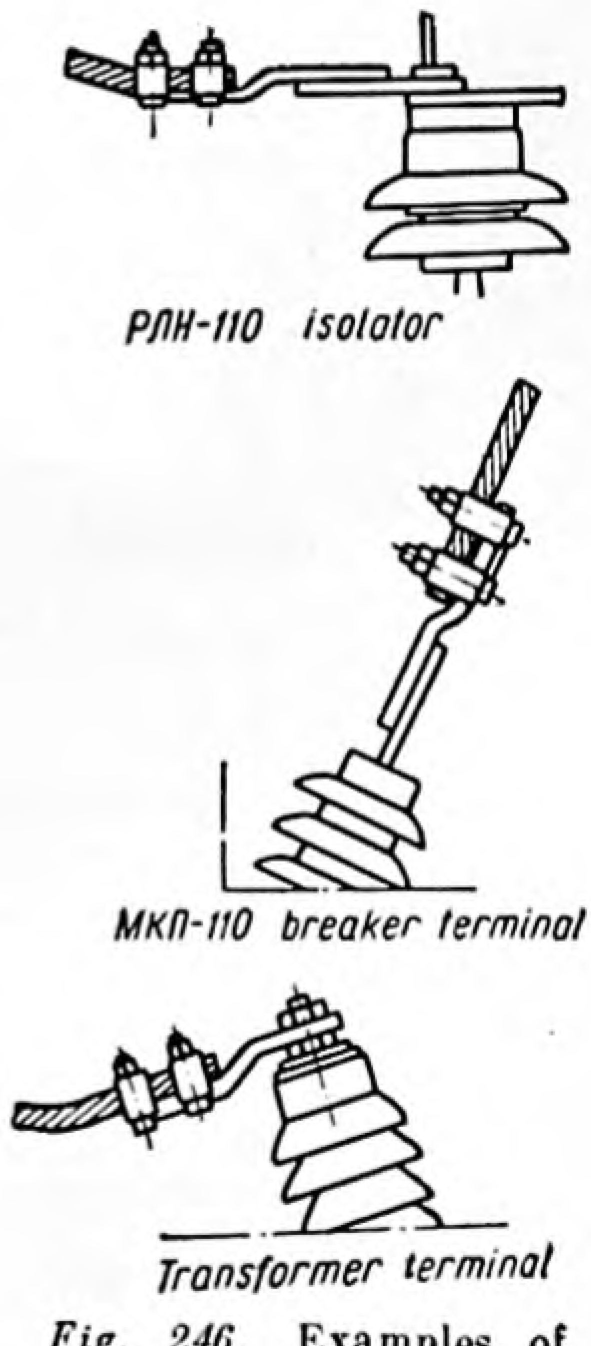


Fig. 246. Examples of outdoor bus connections to apparatus

The cable and the clamp together are attached to an insulator string, and the whole assembly is lifted onto the support by means of a rope and block attached to the cross-arm. This is shown diagrammatically in Fig. 241, while Fig. 242 shows how an insulator string can be attached to a support.

The cable is now strung to the second support by block and tackle or a winch over snatch block (see Fig. 277) attached to the support

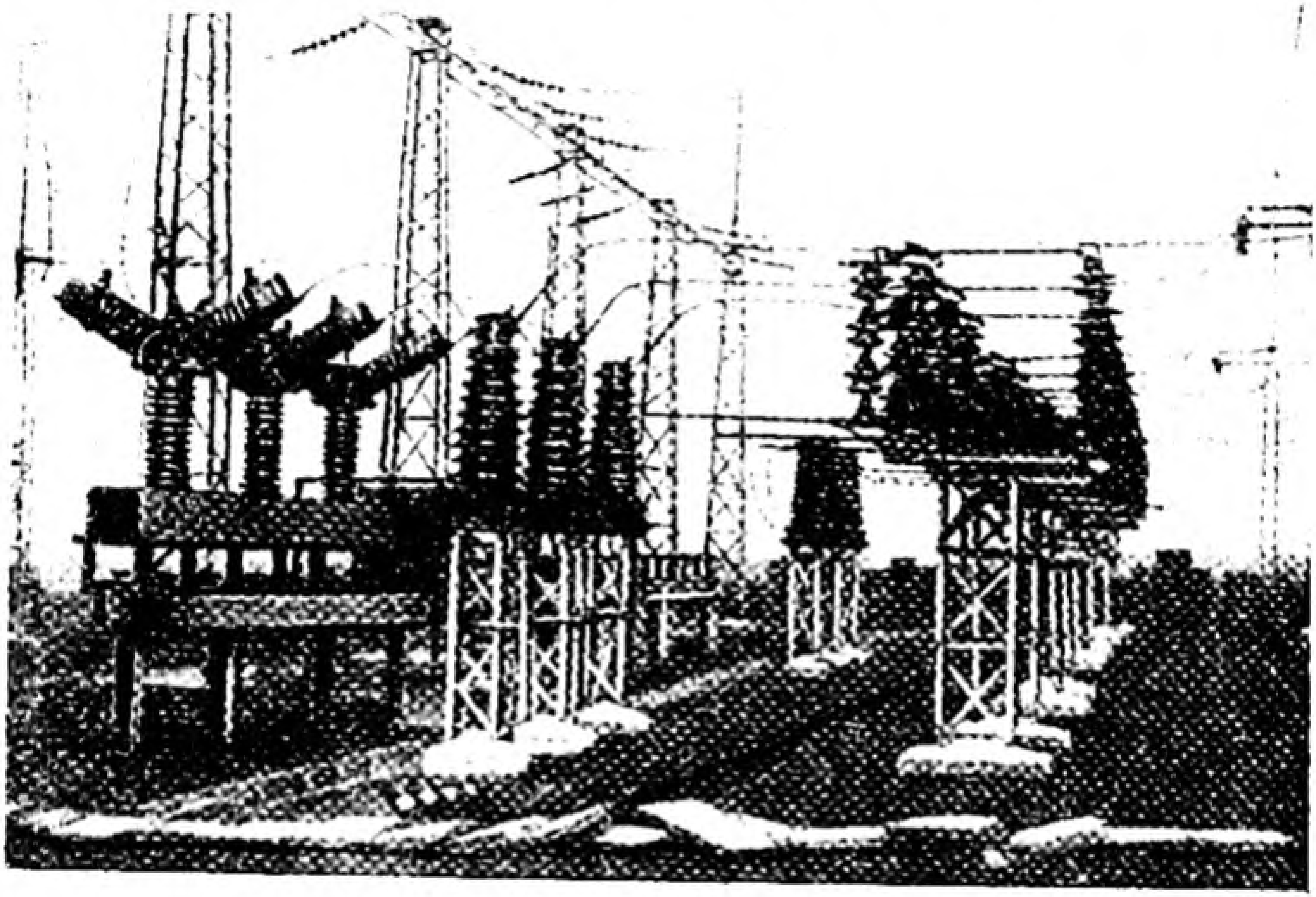


Fig. 247. General view of a bus section in an outdoor substation

cross-arm. The cable is fastened to the tackle or the winch with a wedge or dieplate type of comealong clamp (Fig. 243).

The cable must be tensioned as specified in the design drawings. This may be determined with the aid of a dynamometer placed between the cable and the tackle or winch. In practice, however, the tension is determined from the sag of the cable (see Fig. 285).

The tensioned cable is marked with a binding of soft wire where the insulator string is to be attached to the support, the cable lowered to the ground for the length of the string to be laid off from the wire mark, a tension clamp attached at this point, and the insulator string pinned at the bottom to the clamp. The ready assembly is then lifted to the support cross-arm with block and tackle.

The other two phase conductors are strung in the same way. Their sag is adjusted by parallelling them with the first phase conductor.

The drop leads to the apparatus are connected with bolted-type clamps (Fig. 244*a*), using telescopic derricks, after the main bus conductors have been strung.

Where compression joints or clamps are used (Fig. 244*b*), the tee-offs are marked out and installed before the main bus is strung.

In some cases, the relative position of the apparatus and supports necessitates the use of special steel rods by means of which insulator strings can be spaced most conveniently for dropping a tap-off connection (Fig. 245).

Tee-offs are connected to the apparatus with special bolted-type or compression joints.* Examples of outdoor bus connections to apparatus are shown in Figs 246 and 247.

Problem. Describe the assembly of insulator strings for the bus system of a 110-kv substation.

* The use of compression-type clamps is discussed in Sec. 54.

CHAPTER 5

INSTALLATION OF POWER TRANSFORMERS

38. Delivery of Transformers to the Site

Low-power transformers are shipped to their sites completely assembled, medium-power transformers either completely assembled or with some of the parts dismantled (conservators, vent pipes, etc.) and packed in boxes.

High-power transformers and all transformers from 110 kv upwards are, as a rule, shipped partly dismantled, with their radiators, high-voltage bushings, oil conservators, vent pipes, and air blast system separately packed.

Low- and medium-power transformers are taken to their sites on trucks, while high-power transformers are transported on railway flatcars.

The simplest and most convenient way to unload transformers is by cranes. The truck or railway flatcar carrying a transformer is driven under a crane, all the bracings, stop blocks and wire guys used to secure the transformer in transit removed, the lifting slings attached, and the unit lifted and moved onto a specially prepared unloading platform.

When the truck or railway flatcar can be run right up to an unloading platform having the same elevation as the floor of the truck or flatcar, the transformer can be unloaded by the use of a winch and wire ropes. Where the floor elevations are different, the transformer is placed on blocking built up of railway sleepers and held together by cramp irons.

Where a transformer is moved with the use of a winch and wire ropes, either rails or steel strips must be laid under its wheels.

From the blocking a transformer is brought down a ramp built of railway sleepers, timbers and boards. The most convenient method is when a transformer rides a rail track on its own wheels.

A general view of a 40.5-Mva, 110-kv power transformer is shown in Fig. 248.

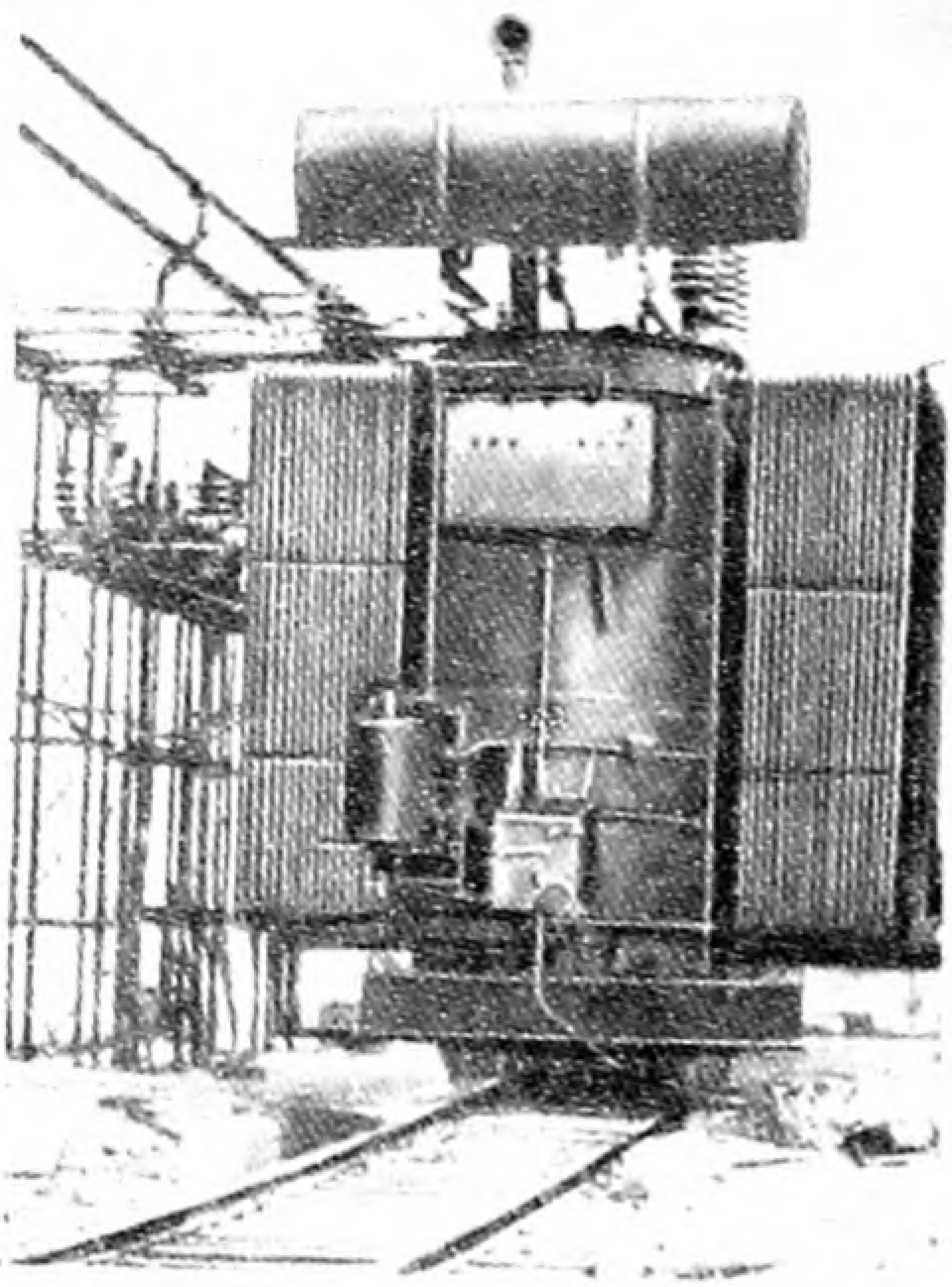


Fig. 248. A 110-kv, 40,500 kva power transformer in process of installation

39. Mounting of Transformer Parts

The radiators. Before mounting a transformer radiator on the transformer tank, it should be pressure-tested and flushed.

A pressure test is necessary in order to make sure that the radiator tubes have not suffered damage. This pressure is usually built up by a column of oil poured into a pipe attached to one of the flanges of the radiator (Fig. 249*a*).

The height of the oil column is made equal to the distance from the lowest point at which the radiator is attached to the transformer tank to the top of the oil conservator, plus 0.5 metre. Defects in radiators detected during the test are remedied on site by electric welding.

Radiators are flushed with clean and dry transformer oil as shown in Fig. 249*b*. The radiator is made to communicate with the atmosphere in order to exclude any possibility of considerable pressure building up inside the radiator.

The first step in the mounting proper is a check to see that the radiator cocks on the transformer tank are fully shut. After this, the blind flanges sealing the outlets to which the radiators are to be attached are removed and their flanges thoroughly cleaned.

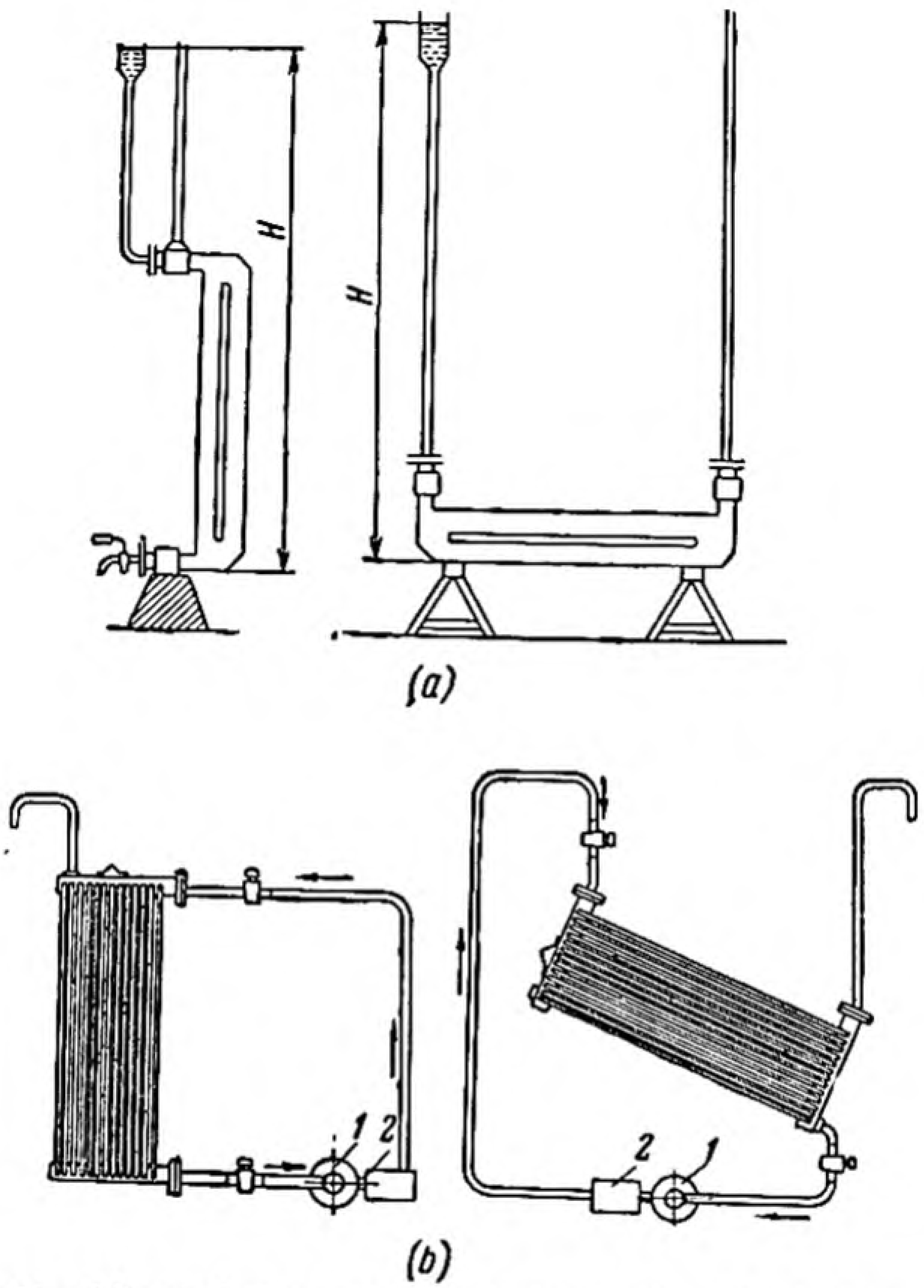


Fig. 249. Method of testing radiators under a head of oil (*a*), and flushing a radiator with oil (*b*):
1—pump; *2*—filter press

The radiator can now be suspended from a hook and its lower flange can be bolted to the corresponding cock flange. A gasket of oil-resistant rubber 10 mm thick with an inside diameter somewhat larger than that of the cock outlet must be inserted between the flanges. The upper radiator and mating cock flanges are then joined in the same manner, and the bolts of both the upper and lower flanges are fully tightened.

When a transformer has no radiator cocks, one of the access covers on its tank top should be removed, the oil drained until it is level with the upper radiator flanges, and the radiators attached to the latter.

The oil is next drained to below the lower radiator flanges, the radiators are mounted on the transformer tank, and oil immediately poured in the transformer level with the upper yoke.

Bushings. On removal from its packing box, every terminal bushing should be cleaned of all packing material and dirt, wiped with a rag moistened with petrol and with a rag moistened with transformer oil.

During visual inspection, the bushing is checked for the oil level, and for broken porcelain and glass parts.

If as much as 10 per cent of the oil has leaked out of the bushing, it should be replenished before mounting on the transformer. A 110-kv bushing takes 60 litres. The oil is poured through an inlet in the upper cap until its level is about 20 to 30 mm above the middle of the oil-gauge glass.

When more than 10 per cent of the oil has been lost, the manufacturer must be informed of the fact.

Before the bushings are mounted, the oil level in the transformer tank must be brought down to 100 mm above the upper yoke (without, however, exposing the yoke insulation) by opening the radiator cocks to admit some of the oil into the radiators. If after this the oil level has not dropped by the necessary amount, the excess oil must be drained.

Next the blind flanges used for transportation are removed from the openings where the bushings are to be mounted, new oil-resistant rubber gaskets are put in place, and welded adapter collars are mounted on them (Fig. 250). The adapter flanges are secured to the transformer cover by bolts which should be uniformly tightened one after another round the bolt circle until the rubber gasket is reduced to half its original thickness. Similar gaskets are also placed on the upper surfaces of the adapter flanges.

Each bushing is lifted by its lifting eye-bolts on its base flange, slowly lowered into the adapter flange until seated on the rubber gasket, and secured to the adapter flange by uniformly tightening the nuts round the bolt circle.

The top terminal cap is now removed from the mounted bushing, a length of wire (or rope) is passed through the central tube, the contact stud soldered to the end of the cable lead is then tied to the wire and pulled up through the central tube. The stud is then fixed in place with a steel pin, the top terminal cap screwed back on, and the lifting eye-bolts removed.

The next operation is to examine, clean and mount the low-voltage bushings. They should be mounted on oil-resistant rubber gaskets in the same manner as the high-voltage bushings.

The drop leads are then connected to the respective bushings. In doing this, the lock-nuts, nuts and washers are removed from the terminal studs in order to slip cushioning pads on each of the studs.

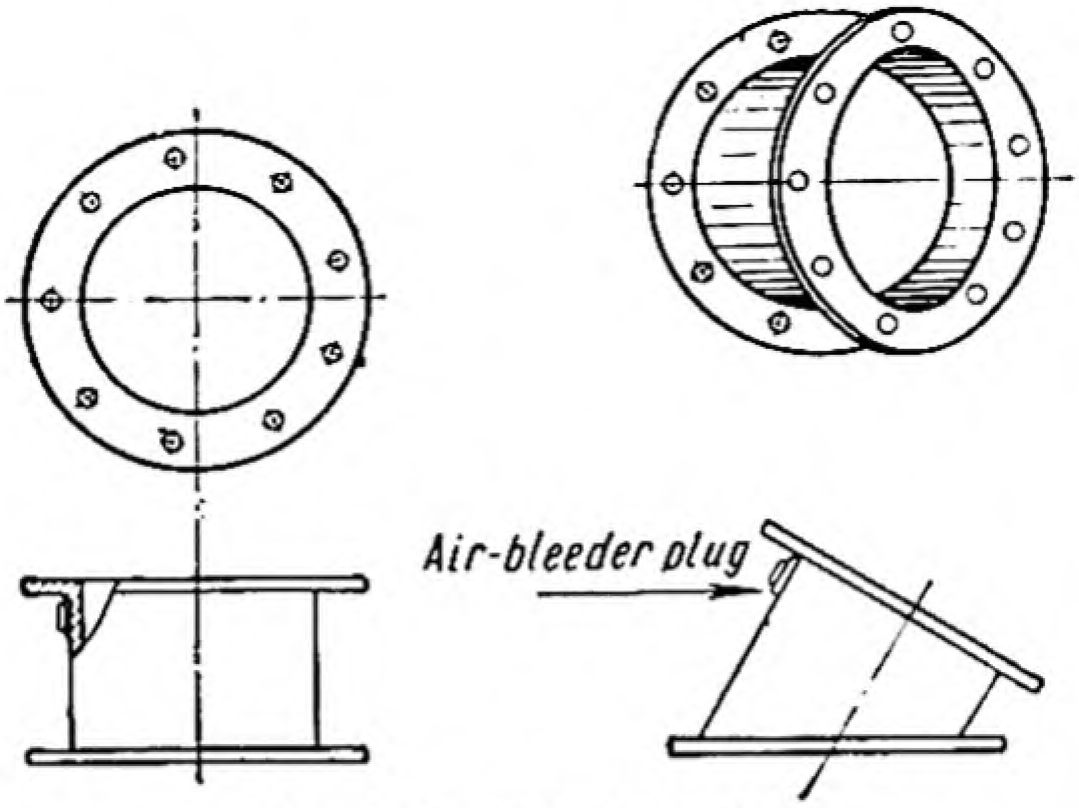


Fig. 250. Adapter collar

Following this, the washers are put back in place and the nuts and lock-nuts screwed down.

The oil conservator and the Buchholz relay. First the remaining oil should be drained at the plug *6* in the sludge sump *5* (Fig. 251), the conservator flushed with dry clean transformer oil, and the oil gauge glass and the connection-pipe cock mounted in place. The conservator may be placed for the time being on two brackets secured to the tank cover.

Now the elbow is removed from the pipe connecting the tank and the oil conservator, and the Buchholz relay is mounted instead, on asbestos-rubber gaskets coated with glyptal or bakelite varnish, taking care to position the sight glass of the relay properly. The position of the relay must be checked with a level. After this, the paper pads inserted for transit are removed from under the floats in the relay and the floats are arranged so that the arrow on the cover of the assembly points in the direction of oil flow to the oil conservator. It should be borne in mind that the sealed connections of the relay should not be taken apart, for they have been factory-tested for oil tightness.

For easy passage of the gases beneath the transformer cover to the Buchholz relay, the transformer must be slightly raised (about 10 mm) at the side where the oil pipe is connected to the conservator. The oil pipe should, in turn, have a slope of not less than 2 per cent. A further requirement is that the oil pipe should not have any bends, pockets and reversed slope which would trap gas bubbles. It is also necessary that the end of the oil pipe line should never be below the transformer cover.

The conservator should be mounted so that the lowest possible oil level in it indicated by the oil gauge is somewhat above the upper

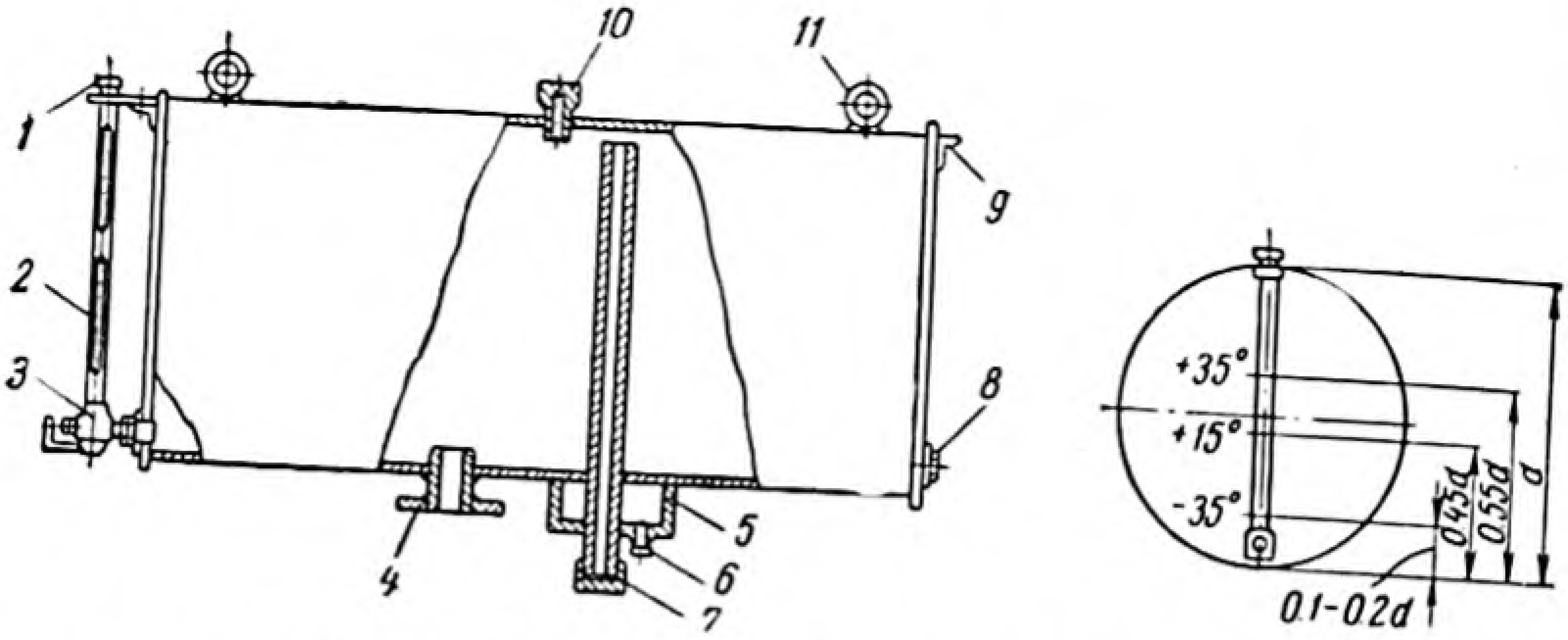


Fig. 251. Oil conservator of a power transformer:
1—oil-gauge cap; 2—oil-gauge glass; 3—oil-gauge body; 4—connection pipe outlet; 5—sludge sump; 6—sump drain plug; 7—breather plug; 8—plug; 9—angle-iron part; 10—oil-filling hole plug; 11—lifting rings

cock of the Buchholz relay. When the Buchholz relay and the oil pipe have been installed, the conservator straps are finally tightened.

The vent pipe and fittings. First, the blind flanges are removed from the transformer cover and from the upper and lower flanges of the vent pipe which is then cleaned and flushed with oil, a glass disk is fastened on its upper flange, an oil-resistant rubber gasket is placed on the transformer tank, the vent pipe is seated and attached to the conservator with a brace, and the presence of the air-bleeder plug on the vent pipe is also checked for.

The thermometers are now installed in accordance with the installation sketch. They may be of the mercury-bulb, mercury-contact, remote-indicating Bourdon-tube and remote-indicating switchboard type. Before installing the thermometers, the corresponding screw plugs are unscrewed in the transformer cover and the thermometer pocket fitting screwed in place with the use of lead washers.

The space between the thermometer pocket screwed into the transformer tank opening and a mercury-contact or mercury-bulb thermometer is filled with oil.

40. Filling of Transformer with Oil and Putting into Operation

After a transformer has been installed, it is topped (filled) with oil. Oil is poured through the access hole which should afterwards be closed and its cover bolted down and sealed with an oil-resistant rubber. Alternatively, oil can be poured through the 2-inch cock on the transformer cover without opening the access hole. The oil must have a dielectric strength of not less than 35 kv by a standard test and not differ more than 5° C in temperature from the oil already in the

transformer. When the oil rises to the tank cover, the remaining oil is poured through the oil conservator, with the cock communicating the conservator with the transformer tank opened only just enough to allow the oil to flow in a weak stream and thus avoid the ingress of excess air into the tank.

In addition and before the final filling, the air-bleeder plugs should be unscrewed on all the oil-filled bushings in order to release the air. After the filling (judged by a stream of oil escaping from the air bleeder openings), they should be screwed in with lead washers placed under them. During the final filling of the transformer the air bleeder plugs on the vent pipe and the bushing adapter flanges should also be opened for escape of the air. The upper cock on the Buchholz relay should also be periodically opened until a stream of oil appears.

Oil filling is discontinued when the oil has risen to 30 or 40 mm above the mark on the oil gauge of the conservator.

It is desirable that the oil be run through a filter press or a centrifugal separator.

The air blast fans are mounted concurrently with the above operations (Fig. 252).

As was stated above, the transformer should be slightly raised on the conservator side for proper operation of the Buchholz relay. For this purpose, steel plates are slipped under the corresponding wheels of the transformer truck. In certain cases the necessary angle of slope is provided when the foundation is laid.

When installing power transformers, utmost care must be taken in handling tools and other loose articles, since anything metallic dropped among the windings and allowed to remain there may cause a breakdown.

After or during the installation work, the small wiring circuits are run to

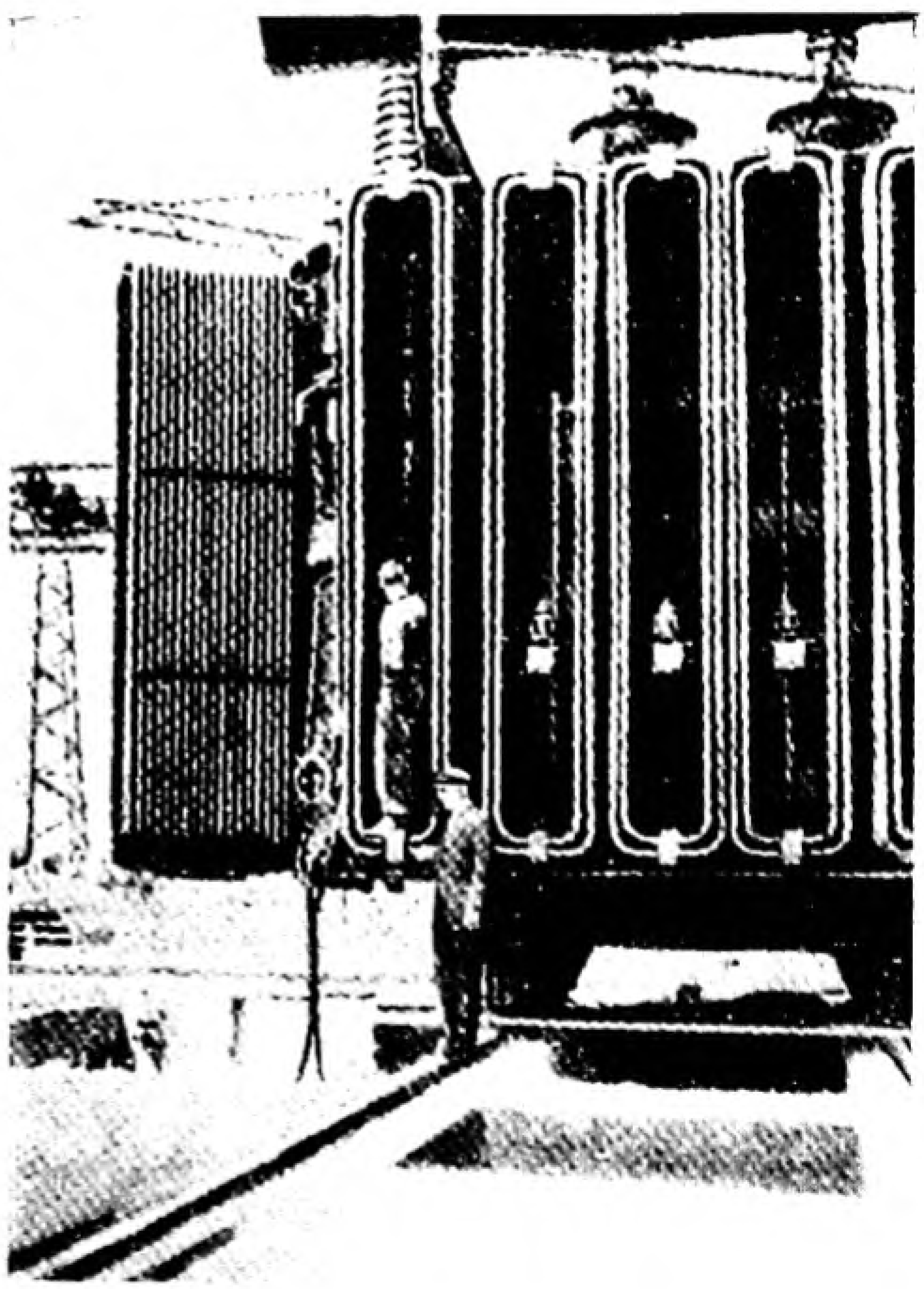


Fig. 252. Power transformer during mounting of air blast fans

the Buchholz relay and the thermometers. If the transformer is installed indoors, the wiring may be laid in rigid metal conduit, using Grade ПР rubber-insulated copper-conductor wire. For outdoor transformers use is usually made of Grade СРГ rubber-insulated lead-covered cable or Grade КСРГ bare, rubber-insulated control cable also laid in rigid metal conduit. The smallest permissible size of wire or cable conductor for this purpose is 1.5 sq mm.

When all the installation work has been completed and all safety checks performed, the transformer is prepared for placing into service. For this, the cocks between the conservator and tanks as well as the upper and lower radiator cocks are checked to make sure that they are open, a final sample of oil is taken for a dielectric strength test, and the insulation resistance of the windings is measured.

When everything is in order, full voltage is applied to distribution and substation transformers at once. In the case of large as well as station interconnection transformers, the voltage is raised, as a rule, gradually from zero to 130 per cent rated value with the generators so that the turn-to-turn insulation may be tested, or any trouble may be discovered before damage results.

In both cases, a steady humming, without loud buzzing or crackling, should be heard.

After a transformer has been tested under the rated voltage, it should be left on at no-load for some time in order that attending personnel and the electricians can examine both the transformer and its connections. Then, the transformer is switched on and off at no-load several times to make sure that the differential relays do not respond to the inrush of the magnetising current.

Following this, the transformer is connected on the secondary side to the load. When the voltage is first applied to a transformer, its relays should be set for instantaneous tripping. Before a transformer may be connected for parallel operation, it is vital to make sure that its nameplate data (ratings, transformer ratio, winding connection, phase rotation group, and impedance voltage) are identical with those of the transformers already in circuit.

The incoming transformer should have its winding connected at the same taps as the operating transformer. This is done with the tap-changing gear with the transformer de-energised.

CHAPTER 6

INSTALLATION OF CONTROL CIRCUITS

41. General

Control and secondary circuits provide the means for control of the power or primary circuits, protection of the electrical equipment, measuring of the electrical quantities in the primary circuits, routine signalling and alarm functions, etc.

Control boards, comprising units housing switches, relays, alarms and instruments are, as a rule, shipped to the site factory-assembled. What is left for the electricians is to mount them to the working drawings and connect them up with the primary and control equipment into an integral system.

Control circuits are usually installed by specialised small-wiring crews. Nevertheless, the switchgear electrician in charge of primary circuit installation should also know the methods by which the control circuits are installed.

42. Installation of Control Boards

After the separate panels of a control board have been received at the site, they must above all be checked by the installation crew for compliance with the working drawings as to their construction, the layout of the electrical equipment, the wiring connections, and the relative arrangement of the panels. The electrical equipment on each panel and on a control board as a whole must be such as specified in the circuit diagrams.

The apparatus and instruments dismantled for transportation and shipped separately packed should be thoroughly inspected for missing parts and possible damage.

The insulation of the panel wiring should be intact. The wires should be run to the instruments, signal lamps, etc., without undue

tension to avoid mechanical stresses at the contacts. The wires and their fixing straps should be laid on insulating pads, and identification tags should be provided on both ends of each wire at the respective device and at the terminal block assembly. Each identification tag should have a legible and indelible marking.

The insulation resistance of all the control wiring, within any one main-connection set should be not less than one megohm.

The surfaces of the panels should be smooth, undented, free of deep scratches and waviness, and all cut-outs for instruments should have smooth edges free from burrs. The frontal surfaces of the panels

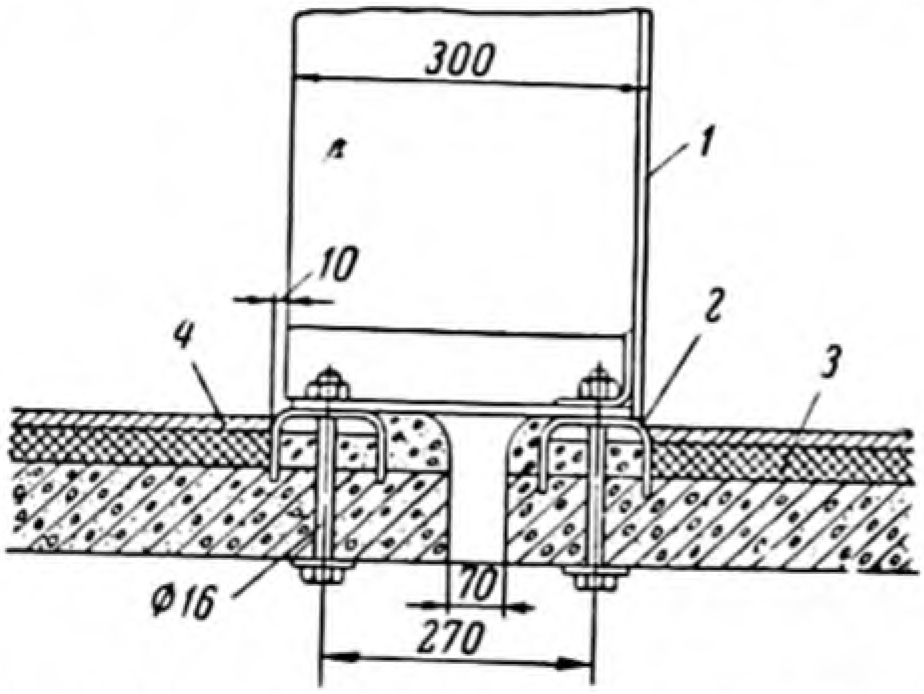


Fig. 253. A way of fixing a control board panel:
1—panel frame; 2—embedded frame of channels, or bent-channel shapes; 3—concrete grouting layer; 4—finished floor surface

should line up in a common plane and be given a priming coat and one finish coat of paint.

A control board is assembled and set up in conformance with the working drawings which must be thoroughly studied in all details before any work is begun.

The panels can be conveniently moved into the control room by a crane and through an opening left in a wall by the builders or through a window opening. Block and tackle or a hoist can be used when a crane is not available.

Inside the control room the control boards may be moved into place over channel with a winch, or block and tackle. It is also possible to move the board units on rollers.

Control board panels are mounted on a supporting frame placed in advance by the builders to the drawing furnished by the electrical contractor and under the supervision of an experienced electrician. An example of a panel secured in place is given in Fig. 253.

The middle panel should be set up first, working each way from it afterwards. The position of the panels on the supporting frame is

checked with a string line, plumb-bob and level. Then the panels are joined together and tack-welded to the frame, each at least at four points.

The supporting frame as a whole is earthed at not less than two points to the earthing system.

All the instruments and devices removed for safety during transportation can now be mounted. To begin with, they must be carefully inspected for broken seals and glass windows, for dents and other traces of damage on the cases.

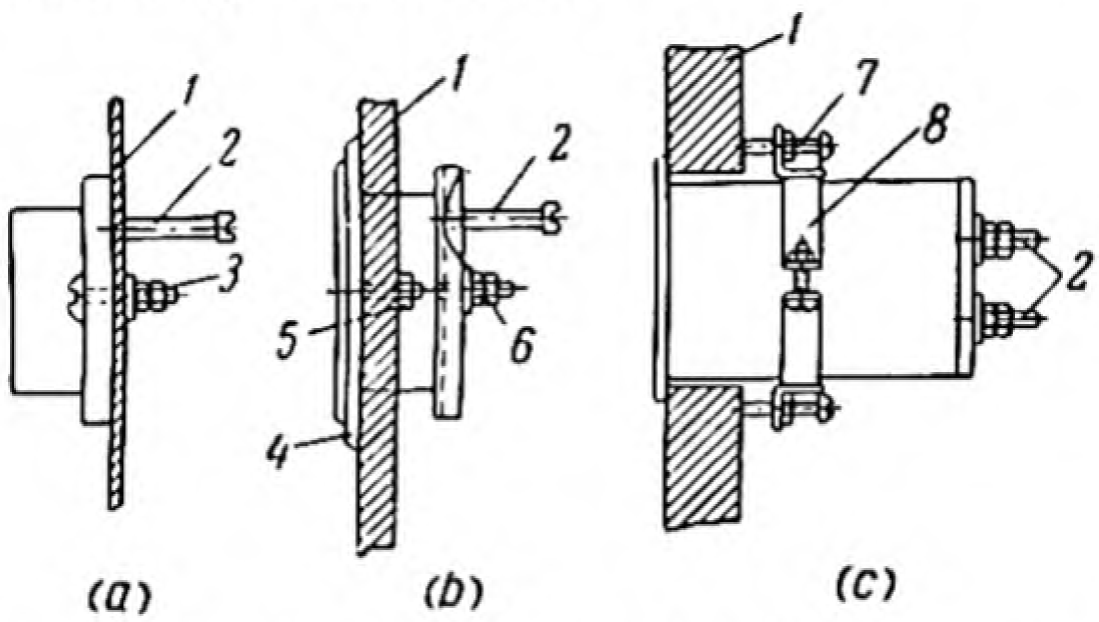


Fig. 254. Mounting and securing of instruments on control board panels:

a—surface mounting; *b* and *c*—flush mounting: *1*—panel surface; *2*—contact stud; *3*—fixing screw; *4*—face ring; *5*—nut for securing face ring; *6*—nut used for securing instrument; *7*—thrust screw; *8*—strap clamp

The instruments and other devices must be mounted to the working drawings of the respective panels. Fig. 254 shows how some of the components of a control board are secured to a panel.

A general view of the boiler house control board of a large electric power station is given in Fig. 255.

In a number of instances the instruments, meters and relays are mounted on separate small-size boards set up directly in the switchgear control aisles (see Fig. 256).

43. Installation of Control Wiring

Control wiring may be classed as panel wiring and general control wiring.

Panel wiring is generally done with ПР rubber-insulated copper-conductor wire or ПРЛ rubber-insulated copper-conductor varnished wire laid and secured on strips of electric-grade cardboard cemented to the panels with bakelite varnish. The wires are secured to a panel with sheet-steel straps fixed by screws (Fig. 257*a*), or by the aid of

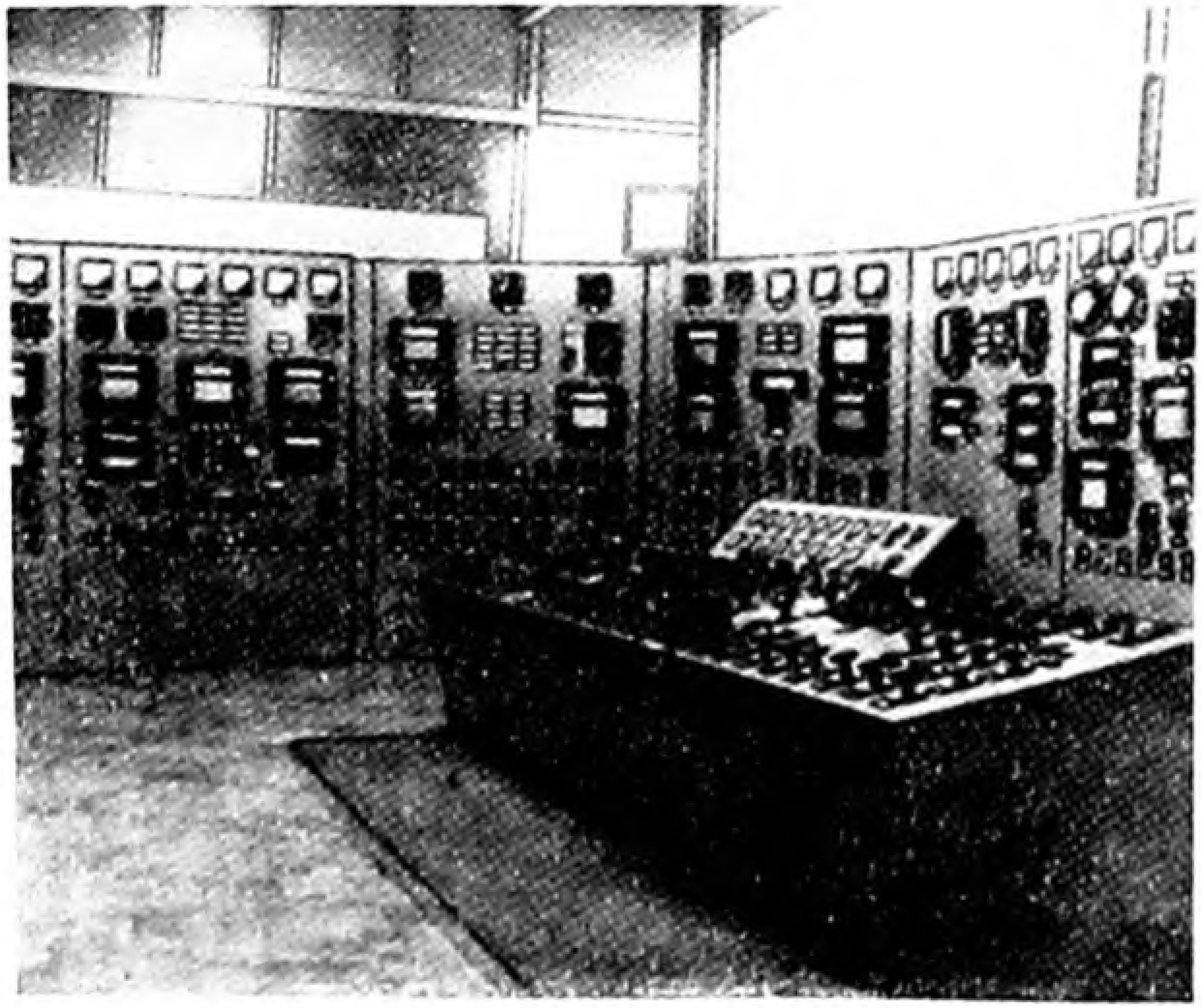


Fig. 255. Boiler house control board in large electric power station

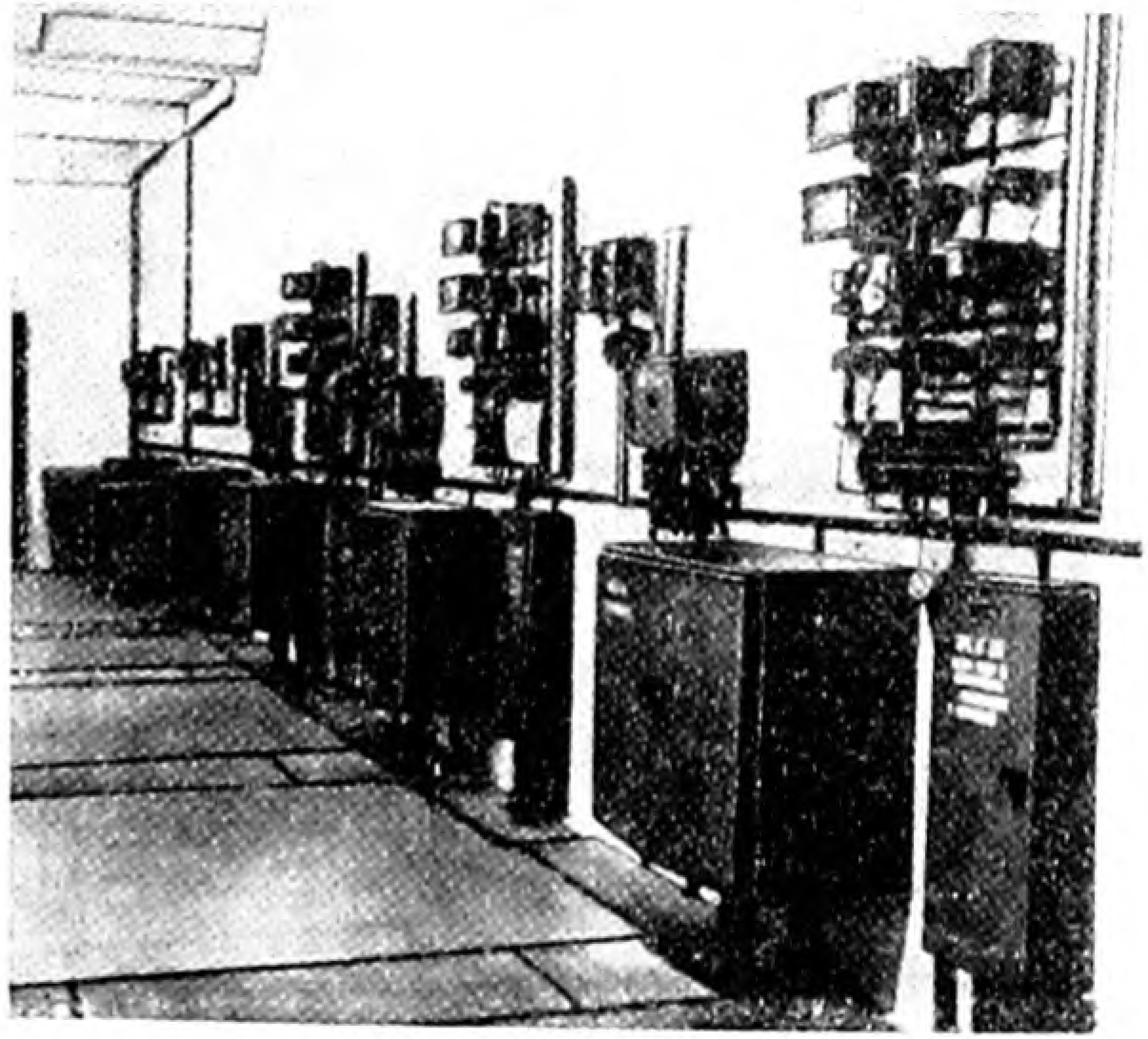


Fig. 256. Control aisle in switchgear section of a power station

spot-welded clips (Fig. 257c). The straps or clips should be spaced 120 to 150 mm apart. A liner of electric-grade cardboard must be placed under the straps or clips.

Another method applied to panel wiring is that of bunched or group wiring (Fig. 258) by which the wires are run without being directly secured to the panel surface. The wires leaving a terminal block in the same general direction are grouped into bunches arranged in a convenient manner. Each bunch is formed to have a rectangular

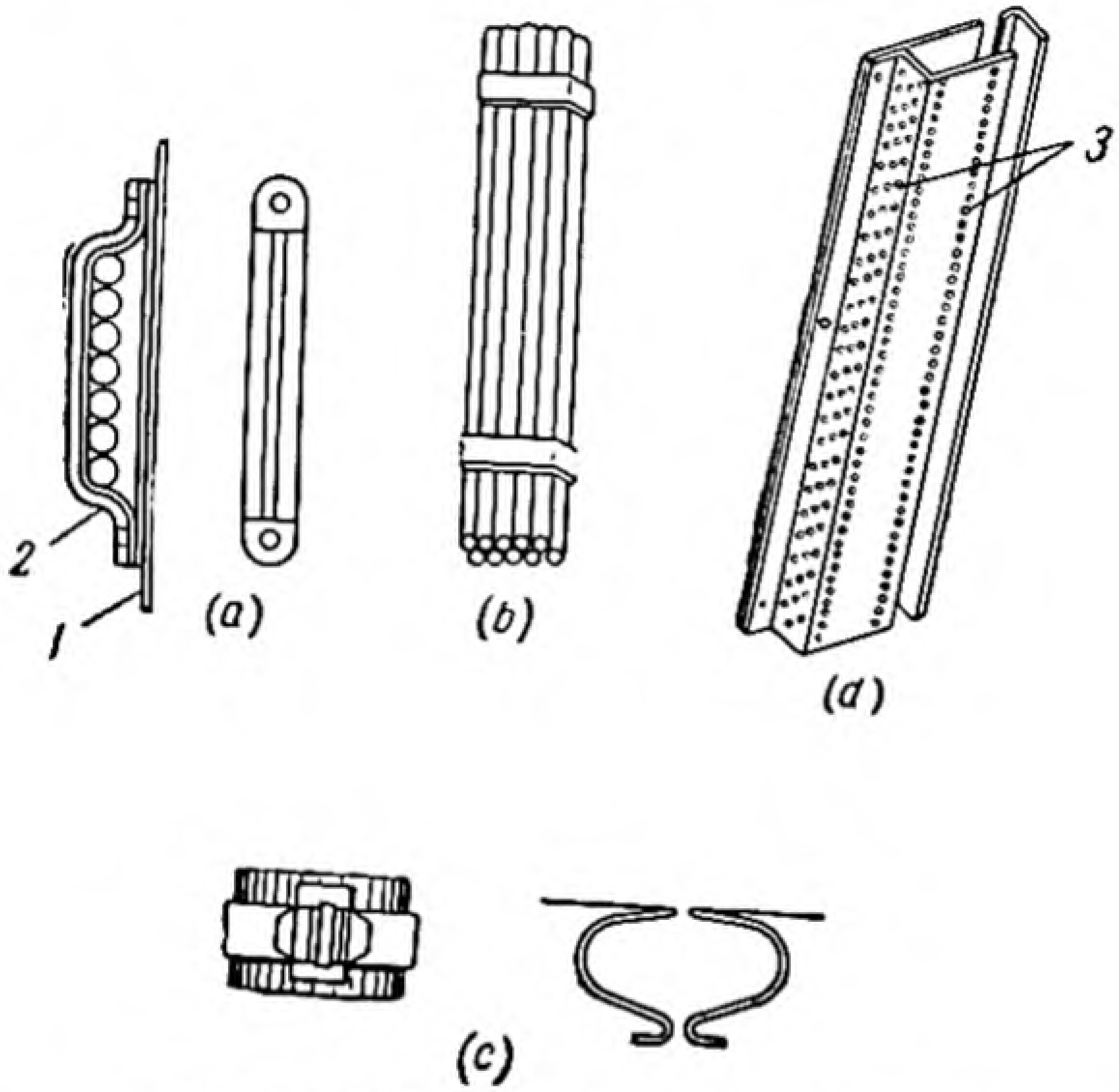


Fig. 257. Methods of panel wiring:
a—by straps secured to panel sheet; *b*—by bunching; *c*—by panel clips; *d*—in perforated ducting: *1*—panel sheet; *2*—insulating liner; *3*—holes for exit of wires

cross section and is held together by metal straps spaced up to 200 mm apart on the bunch.

The straps are made from tin plate 0.3 to 0.4 mm thick, or from sheet aluminium as thick as 0.6 mm. To avoid damage to the insulation, liners of thin electric-grade cardboard are placed under the straps which are locked on the bunch by means of a fold-over joint or a buckle (Fig. 257c).

The wires in the bunches are connected to the panel terminal block at one end and to the terminals of the respective devices at the other. When the run of a bunch is over one metre, it should be secured by brackets to the panel at intermediate points.

Still another method is to bunch wires around a steel bar 5 to 6 mm in diameter, welded to the panel. The bunches are secured to their bars by straps as in the previous method.

Panel wiring can be greatly simplified and its cost reduced by the use of perforated ducts or gutters which make it possible to dispense

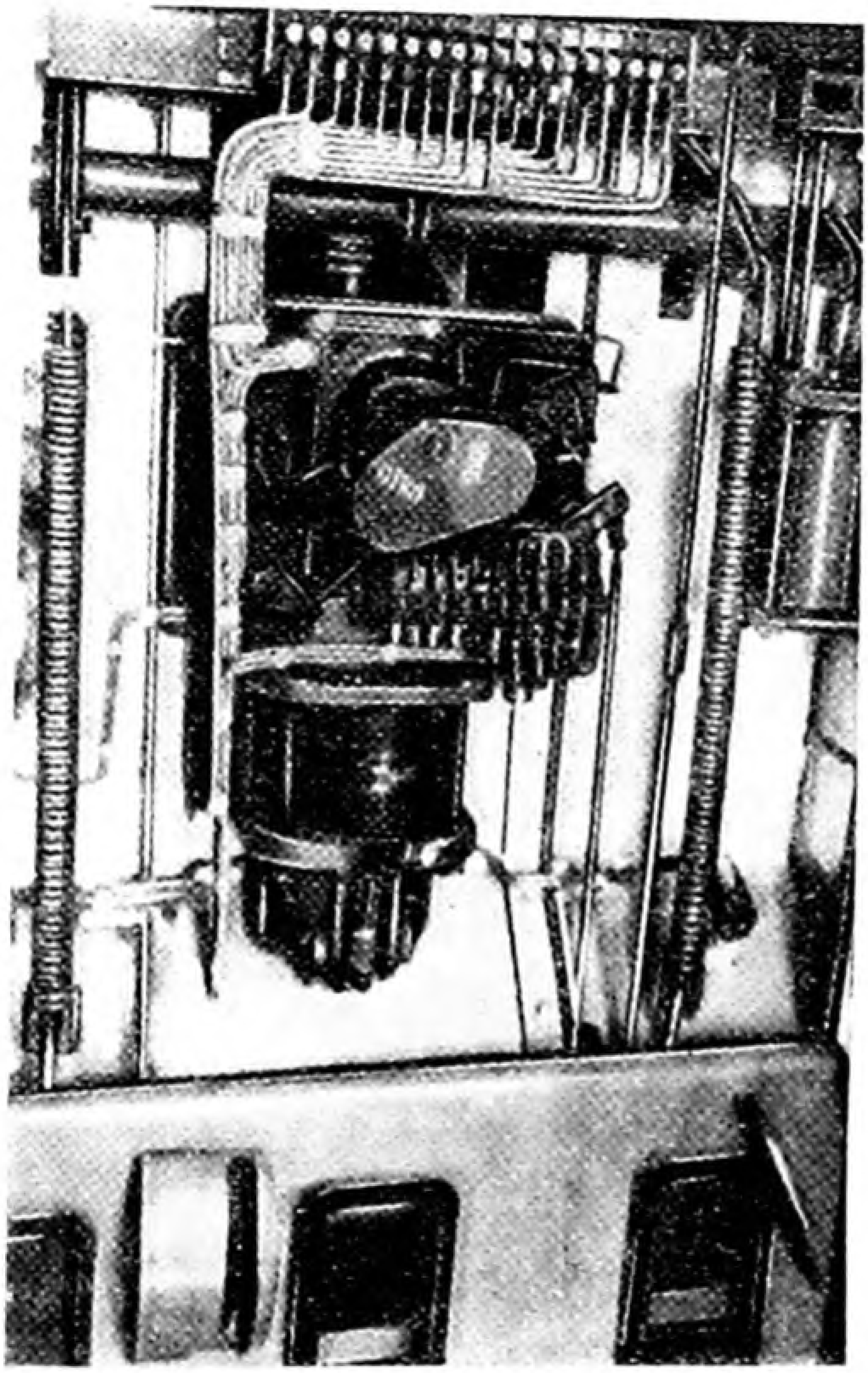


Fig *258.* Bunching in wiring a ПС-10 solenoid operating mechanism

with the labour-consuming operations involved in the usual wiring methods.

A perforated duct (Fig. 257*d*) has holes in which insulating grommets are inserted and through which the conductors may be brought out without danger of damaging their insulation. At the lower end of the duct a terminal block is fixed, from which the conductors,

loosely bunched and tied together at a few points, are passed upward into the perforated duct-way. The wires are brought out through the insulating grommets at the proper points for connection to the terminals on the various devices.

In the latest types of perforated ducts the terminal block is located on the duct between two rows of holes and thus makes it possible to connect the wires to the terminal block immediately where they leave the insulating grommets.

Gutter wiring consists in laying the wire bunches into their ducts and bringing their ends out for connection to the devices and the terminal block. Before installation, gutters must be given two coats of insulating varnish.

General control wiring, or wiring outside the panels, is widely done with ПР rubber-insulated copper-conductor wire run on insulating cleats. Cleats may be made of ebonite, textolite, moulded phenolic plastic, laminated insulation, and hard-woods (oak, beech) boiled in transformer oil. To flat surfaces cleats may be secured by cemented-wire-spiral and screw fixings, anchor studs, or with the aid of metal supports. Cleats should be spaced at intervals of 300 to 350 mm.

Before it is cleated, a wire is pulled for straightening through a paraffin-soaked rag. The wire is then clamped in a cleat at one end, strung taut, clamped in the cleat at the other end, and is finally clamped at the intermediate cleats.

Care must be taken not to deform the wire by excessive pressure, as it is practically impossible to straighten it once it is clamped in a cleat.

Cleated wiring is usually covered by box-shaped steel capping which gives it a neat and finished appearance, and protects it against accidental injury.

Control circuits in indoor substations may be put in with ПР wire laid in box-like wireways made of sheet steel 2 to 3 mm thick. These wireways usually come from outside suppliers already drilled and tapped for strap fixing of the wires.

These wireways are fixed to the supporting surfaces by anchor studs, cemented-wire-spirals and screws, or welding. The bottom of a wireway should be lined with pressboard or varnished cloth.

Wires may also be laid without wireways. Instead strips of press-spahn or varnished cloth are pasted to the concrete surfaces of the indoor substation structure to protect the insulation, and the wires are fixed, as in wireways, by means of straps.

The control circuits of indoor substations to a great extent are put in with control cables of the rubber-insulated СРГ, ВРГ, КСРГ and КВРГ grades which are run over the surfaces of the switchgear room and on metal supports.

9*

Where straps are used, the cable runs are made by marking out two lines of fixing holes per run; where clips are used, only one line of holes per run is marked out. Fixing straps or clips are spaced on centres of 300 to 350 mm.

Straps are fastened on brickwork and concrete surfaces with anchor studs. Clips are made from tinplate or sheet aluminium strips 1.5 to 2 mm thick and 8 to 10 mm wide, which are grouted in with gypsum mortar in holes drilled beforehand.

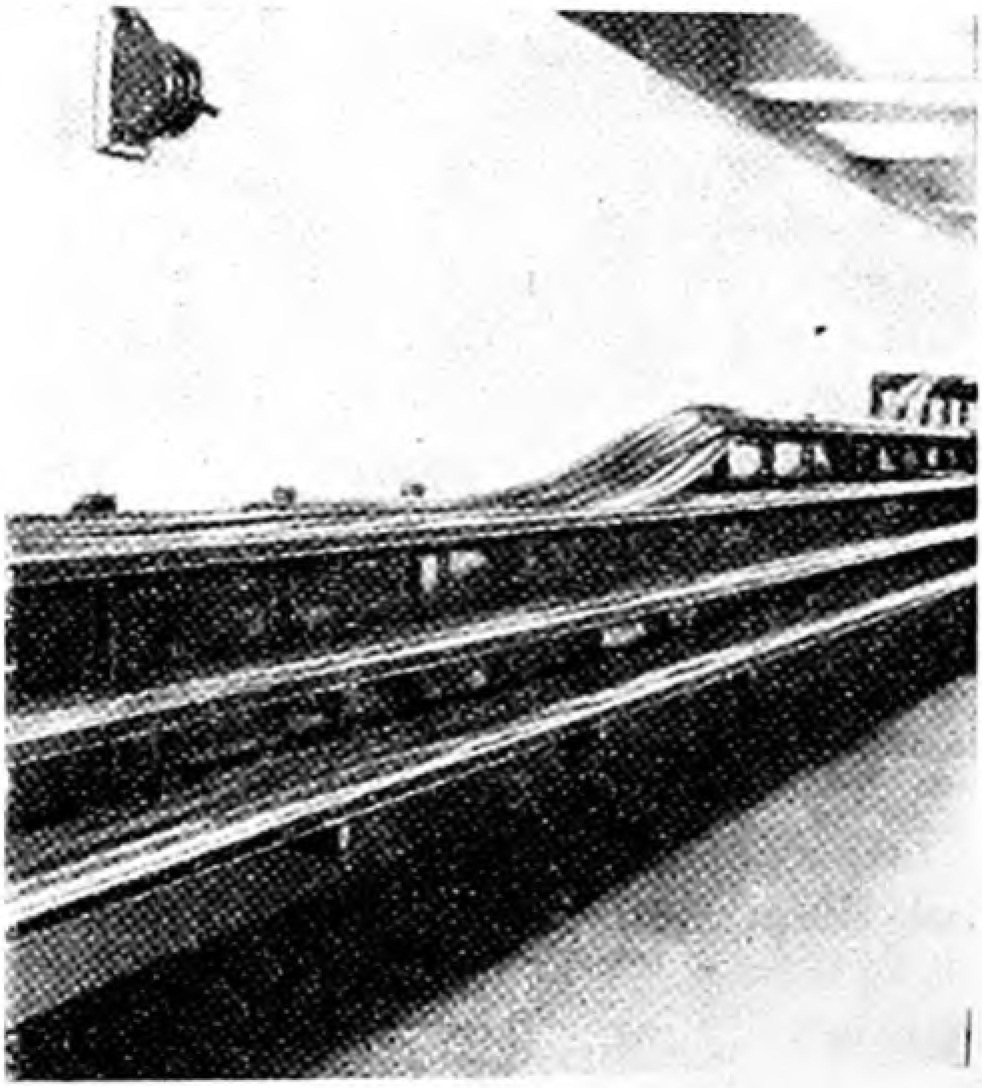


Fig. 259. Control cables within indoor switchgear structure of a power station

When CPГ and KCPГ lead-covered type cables are fixed with straps or clips, the smallest radius to which they may be bent when passing around obstacles or corners should be 8 to 10 cable diameters; for BPГ and KBPГ p.v.c.-covered type cables the minimum radius of bending is 5 to 6 cable diameters.

Installation of a cable begins with measuring off the length of cable required, after which the cable is put in under the straps or in the clips along the run, straightened and finally fixed along its entire run.

To avoid damage to the lead sheath of CPГ cable, pressboard liners must be placed between the cable and the straps or clips.

Where a cable must be carried through a wall or floor an appropriate length of $^1/_2$-inch to $^3/_4$-inch rigid steel conduit should be put into

the hole and the ends of the conduit expanded and slightly flanged. Where a cable is run from one storey to another, the steel conduit should protect the cable to a height of 2 metres above floor level. In such cases the conduct pipe is fixed with 2 to 3 straps.

Where various obstacles are to be passed, such as other cables, metalwork, earthing conductors, the cables should be run in a neatly smoothed groove.

All cable connections and tappings should be made up within the terminal-block cabinets.

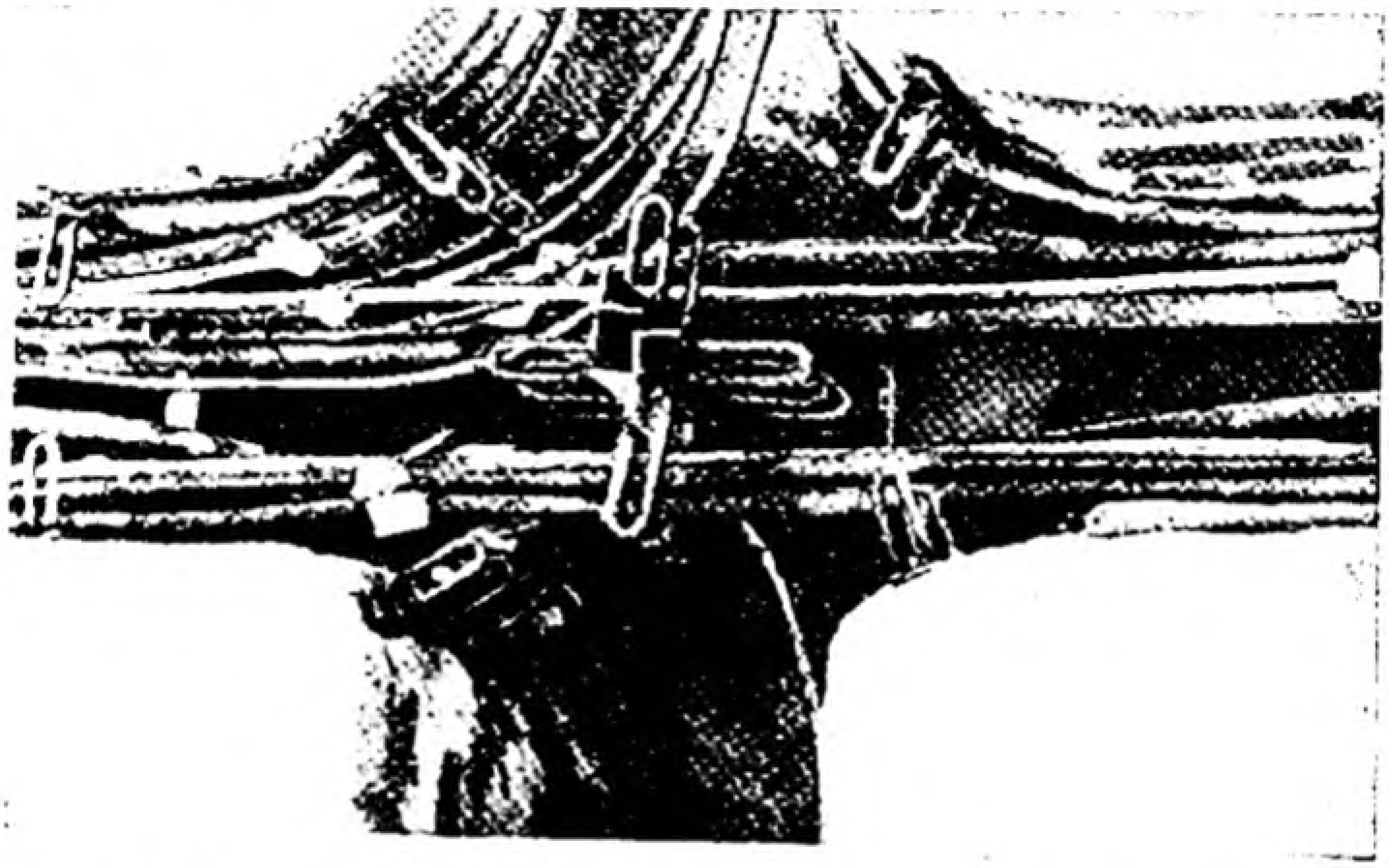


Fig. 260. Cables in the trenches of an outdoor substation (in process of work)

ПР wire used for control wiring outside control boards may be laid in rigid steel conduit fixed to the structural surfaces by straps or by tack welds to the metalwork or embedded metal inserts.

Lines connecting the switchgear and the control board are mainly made with armoured control cables such as Grades КСРБ, КВРБ, КСБ, and КСБГ. Such cables are run on the surfaces of the structure, in floor ducts, basements, tunnels or wells.

These cables widely use a variety of metal supports manufactured by outside suppliers or, where the demand is limited, made directly on the site. An example of control cables laid in an indoor substation is shown in Fig. 259. The supports for such cable runs are generally constructed from $40\times40\times4$ mm angle iron, 5 to 7 mm diameter wire rod, and 50×4 or 40×4 mm steel strip.

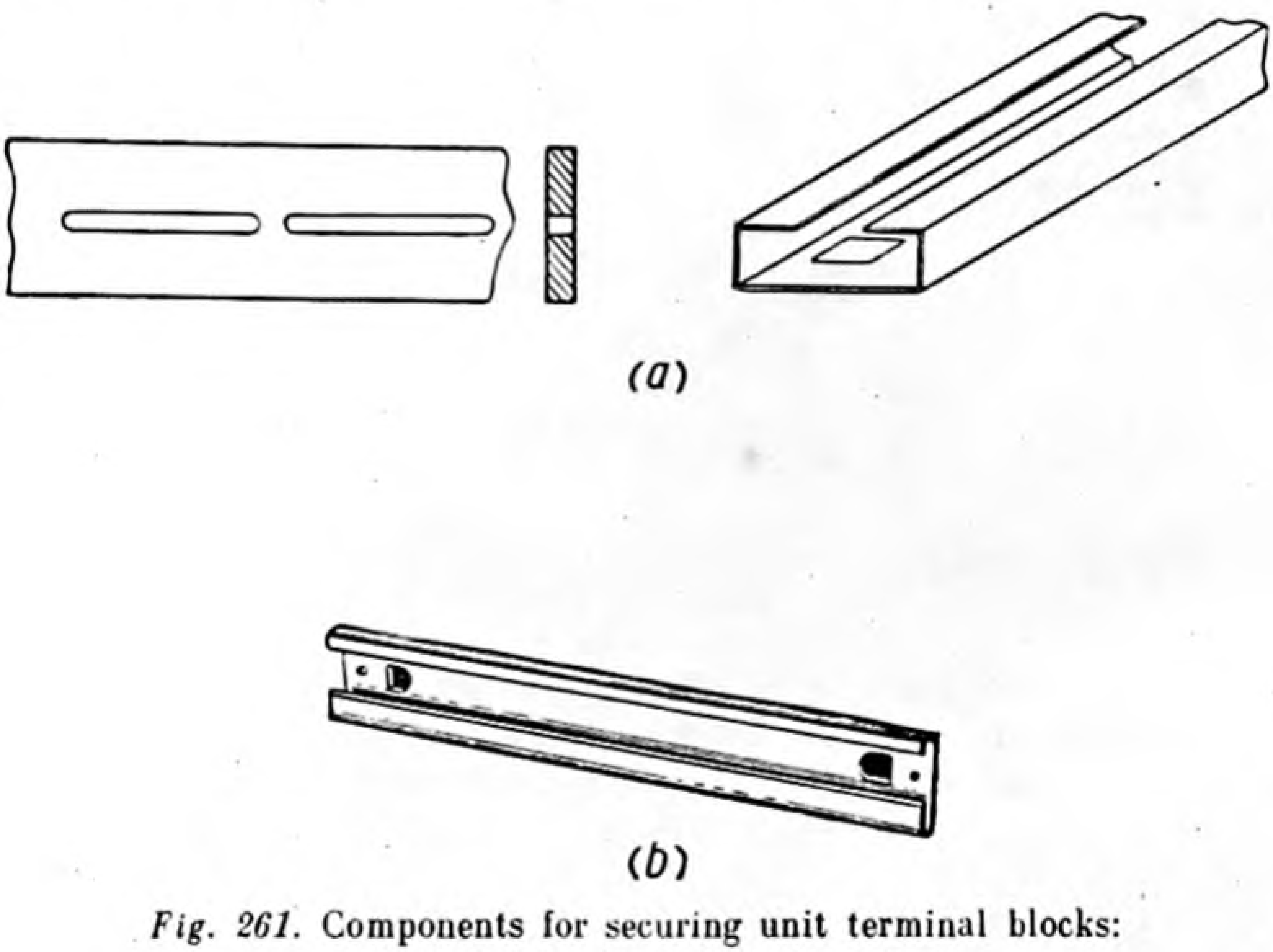
The supports are grouted in at their locations, after holes have been marked out and drilled in advance. A method widely used today

is to weld cable supports to metal inserts embedded during construction by the builders.

In outdoor substations the control circuits are generally installed with armoured control cables such as Grades КСРБ and КСБ laid in cable trenches (Fig. 260). Where the cables are brought out to switchgear equipment they are enclosed in rigid steel conduits up to 2 metres high for protection from mechanical injury.

44. Fanning and Connection of Wires and Cables at Terminal Blocks

All connections in control circuits are made at terminal blocks secured on 30×3 mm strip steel supports, for which purpose perforated strip (Fig. 261*a*), or special-section shapes (Fig. 261*b*) are used.



(a) (b)

Fig. 261. Components for securing unit terminal blocks:
a—perforated strip; *b*—special-section shapes

A block must have as many terminals as there are circuits in a given system, which is determined from the wiring diagram.

A row of terminals should be placed 75 to 150 mm away from the centre line of the last fixing strap of the incoming conductors.

Before the panel wires may be connected to a terminal block, their ends should be straightened by pulling a paraffin-soaked rag over and down the wire, taking care not to damage the insulation at the straps.

It is a good plan to back off one of the screws on the last strap when straightening a wire, after which the wires are laid back in place and the screws are tightened again.

Fanning-out, or the arrangement of the wires, should be started at the extreme terminals. The outer wire is measured off, bent, skinned and inserted under the respective terminal. Then this procedure is followed with the wire next to it. The two wires are straightened in a horizontal plane, and the same operations are repeated with the next conductors, gradually progressing towards the centre, the extreme wires serving, so to speak, as templates for the other wires (Fig. 262*a*).

In order that a wire be kept in place in the course of work, it should be temporarily tied with a piece of cotton tape.

Where there are more than 50 wires, they have to be arranged in several rather than in one layer as shown in Fig. 262*b*.

A method which also finds use is "broom" fanning (Fig. 262*c*).

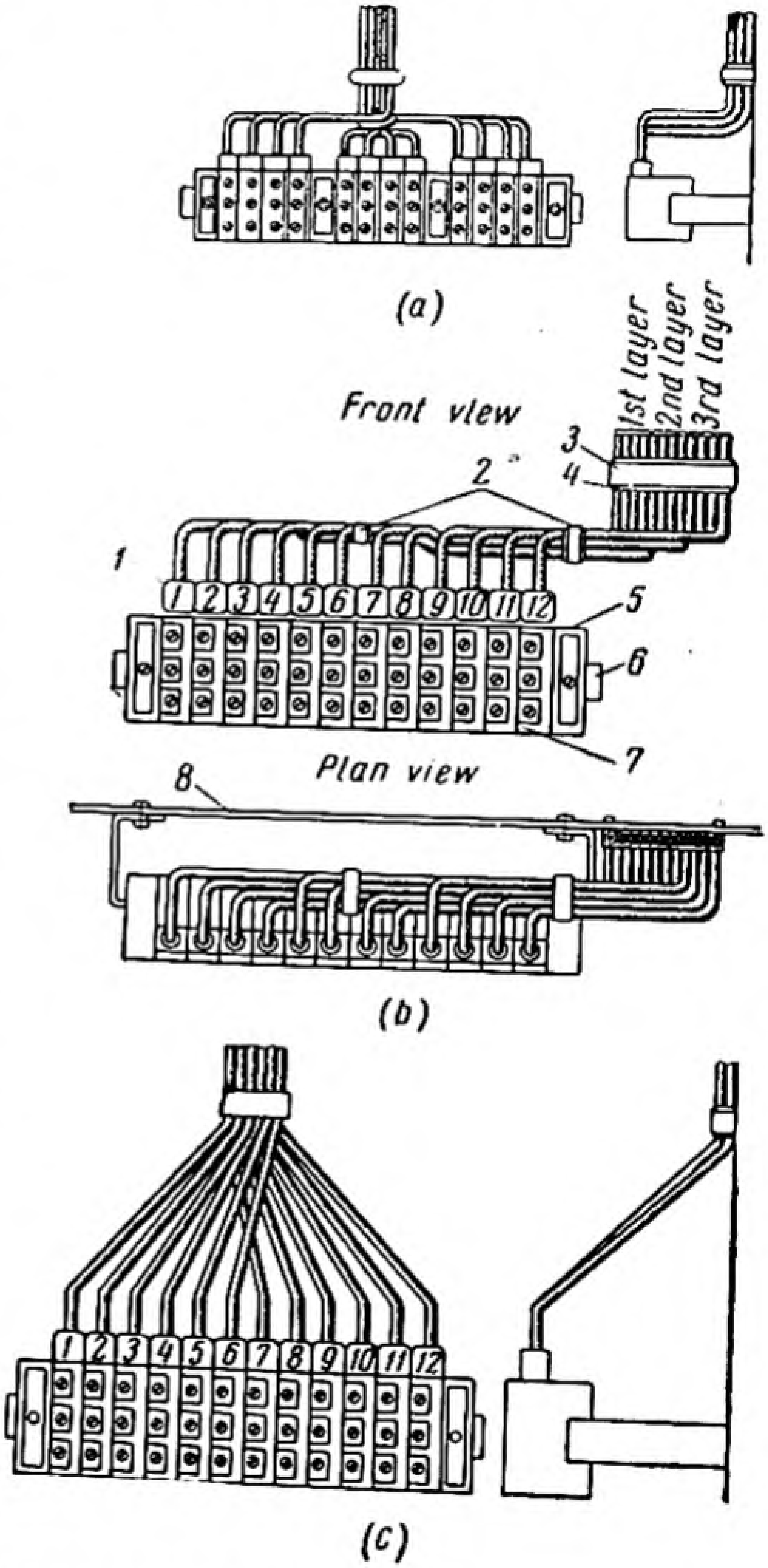


Fig. 262. Examples of fanning out of wires at a terminal block:
a — single-layer arrangement; *b* — multilayer arrangement: *1*—marker block; *2*, *3*—bunch bindings; *4*—insulating linking strip; *5*—terminal block units; *6*—clamping strip; *7*—terminal; *8*—support surface; *c*—"broom" fanning

Before control cables brought up to panels may be connected to their terminal blocks, they should be terminated in a manner

depending upon the type of cable and its location—i. e., indoors or outdoors.

In the case of KCPГ bare lead-sheathed, rubber-insulated control cables used in indoor substations so-called "dry" termination is practised. For this, the lead sheath is removed for a length sufficient to make the necessary connections, the trimmed end of the sheath is belled out with a wooden drift, the rubberised fabric tape serving im-

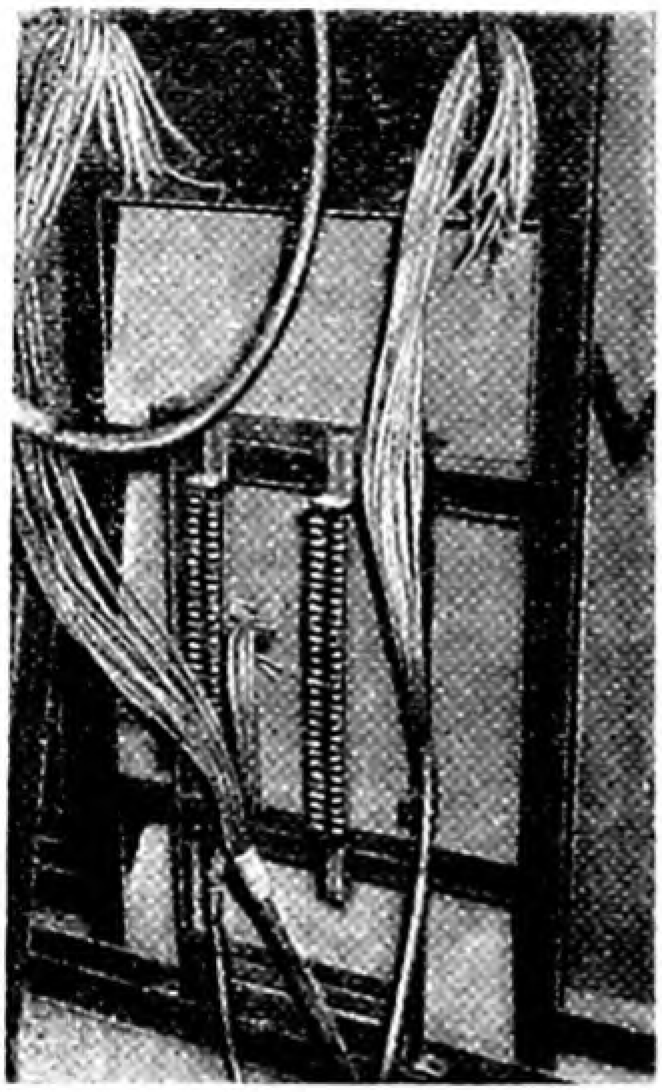


Fig. 263. Control cables brought up to terminal block (in process of installation)

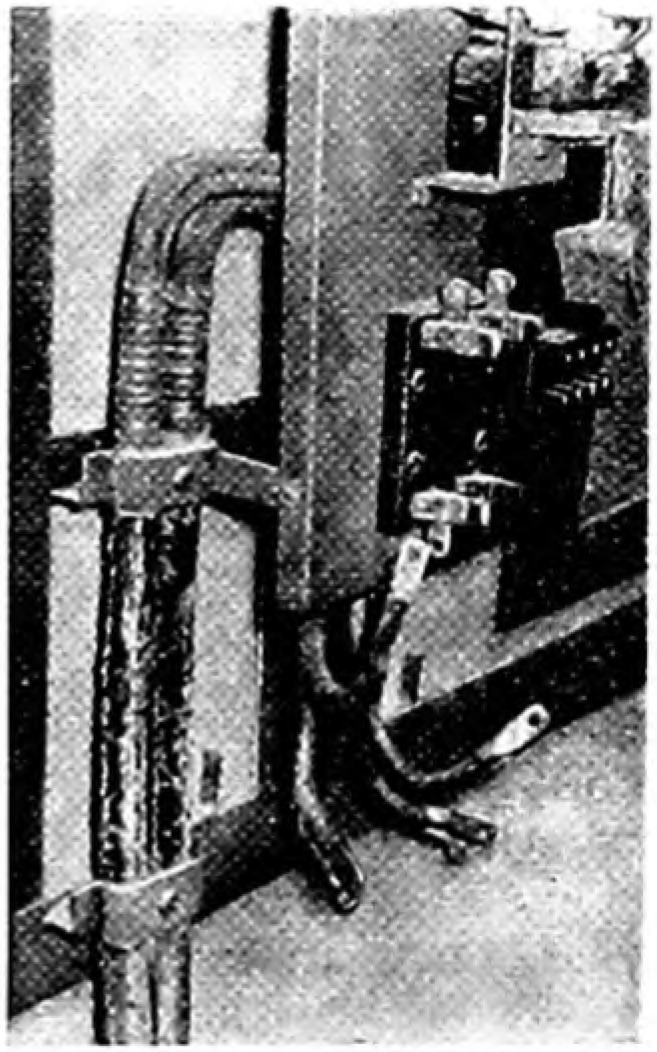


Fig. 264. Control cables brought up to a contactor panel

mediately under the lead sheath is unwound to leave a belt of 15 to 20 mm which is secured with 1.5 to 2 layers of p.v.c. adhesive tape.

The cable conductors are then slightly spread apart, straightened, and p.v.c. sleevings are slipped over the rubber insulation as far as the rubberised fabric belt to protect the rubber insulation from premature ageing.

After this, thin twisted cord is wrapped for a distance of 25 to 30 mm from the belled end of the lead sheath and coated with bakelite varnish.

Recent practice is to serve the "root" with adhesive p.v.c. tape applied 15 to 20 mm back of the trimmed end of the lead sheath and run upwards for a length of 30 to 40 mm.

Another method for sealing the "root" is to apply a piece of p.v.c. tubing split along its length, heat its outer end, and press it against the main wrapping for bonding.

Examples of control cables brought out to a terminal block and to apparatus in an indoor switchgear are shown in Figs 263 and 264.

In outdoor substations, where paper-insulated control cables are primarily used, the cables are terminated with compound-filled sealing ends made of roofing steel or a moulded plastic. Cable ends in both types are terminated almost identically, as described just below (Fig. 265). First, the cable surface is cleaned of all dirt, and the length to be bared for termination is measured off. At the point measured off, a length of soft binding wire or of cable-armour tape is wrapped around the cable. In the latter case, a tinsmith's folded joint should be made. A sealing end fitting may now be slipped on the cable and pushed down out of the way.

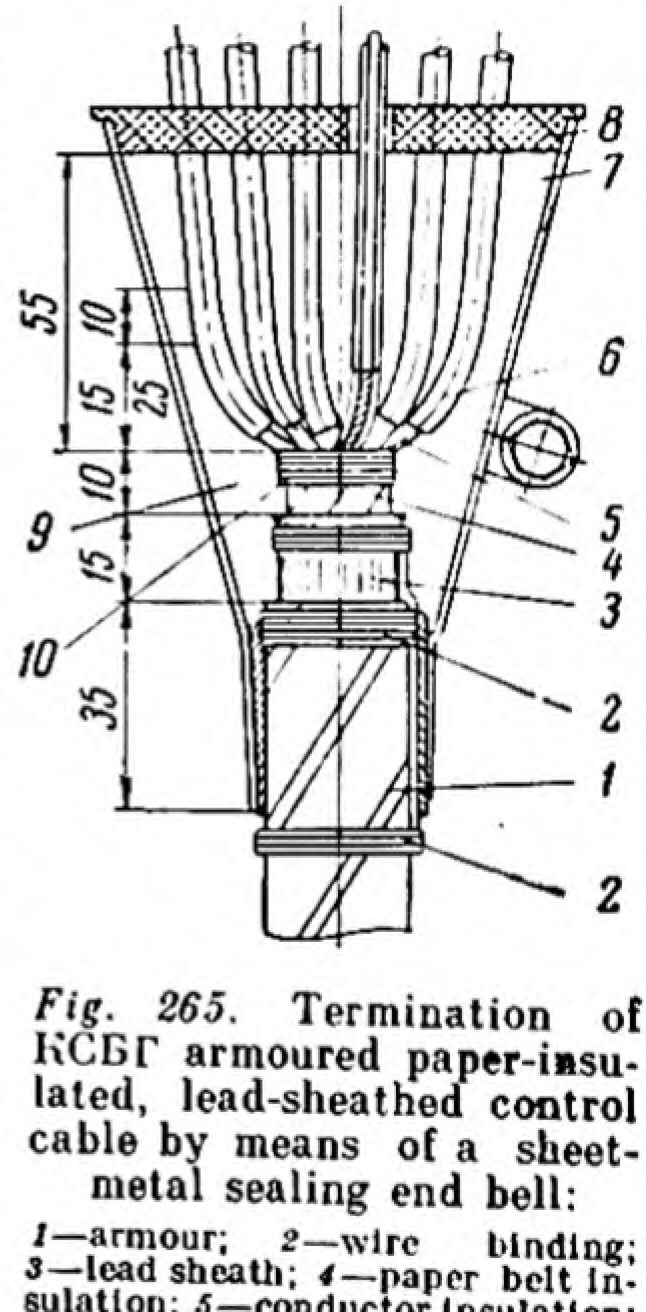


Fig. 265. Termination of КСБГ armoured paper-insulated, lead-sheathed control cable by means of a sheet-metal sealing end bell:

1—armour; 2—wire binding; 3—lead sheath; 4—paper belt insulation; 5—conductor insulation; 6—p.v.c. tubing; 7—sheet-metal end bell; 8—spacing plate; 9—cable-compound filling; 10—wrapping of unbleached thread or cord

The armour is then cut within 3 to 4 mm of the binding on the armour and towards the cable end and removed.

The various protective coverings and belt insulation down to the core insulation should be removed so that the remaining surface is graded off. The step formed by the lead sheath should be 15 to 20 mm long, and that of the belt insulation, 10 to 15 mm long. A wrapping of 10 to 15 turns of unbleached thread is then applied to the belt-insulation step.

The cable conductors are then separated, coated with p.v.c. varnish, and a length of p.v.c. tubing of suitable diameter is slipped over each conductor.

Next tarred tape is wound in several layers over the binding at the end of the armour, for about the length of the throat in the sealing end fitting. It should be sufficiently thick to provide a close fit between the throat and the tarred tape surface and thus prevent escape of the filling compound. The sealing end fitting is then slipped onto the packing tape, positioned vertically and temporarily fixed in place for filling with cable compound.

Sealing ends are filled with МБМ compound at a temperature of 140°C. As soon as a sealing end is filled, the cover put on the conductors in advance is pushed down in contact with the compound before it solidifies.

Upon cooling, the sealing end is cleaned of excess compound, secured to the support, and given a coat of asphaltic varnish.

Cable terminations are usually located in equipment cabinets or in special terminal-block boxes.

Connection and arrangement of the separate conductors of a terminated cable is carried out according to the usual methods explained earlier.

45. Mounting of Storage Batteries

Direct current operative supply for the control circuits is provided by storage batteries installed in special rooms with an asphalt-covered or tiled floor and ample ventilation to remove the gases and sulphuric acid fumes evolved by the batteries.

Storage batteries are mounted on racks (Fig. 266*a*) made of wooden bars 130×75 mm in cross section and placed on wooden pedestals supplied with glass tops or pads. The wooden parts are primed and given two coats of linseed oil and acid-resistant paint.

Alternatively, racks can be made from steel channels secured on support insulators (Fig. 266*b*).

The storage battery racks should be properly levelled and plumbed, or else even the slightest unevenness may result in the cracking of the glass storage battery jars.

Mounting of storage battery jars. Before placing on racks, the jars should be thoroughly inspected for possible breakage, damaged lead plates, and other defects, washed out with pure water and wiped dry with lint-free cloths.

The lead plates should be cleaned with a soft brush, wearing a respirator mask as protection against lead poisoning.

The jars are placed in line and equidistantly from the longitudinal axis of the rack, and on conical glass insulators so that their bottoms rest on the broad ends of the insulators. In the case of racks made from steel channels, each insulator must be placed on a lead washer which, apart from serving as a pad, is also used for levelling the jars, done with a straight edge and spirit level.

Depending upon the type of cell installed, the jars must be spaced 30 or 65 mm apart, as specified in the working drawing.

The plates in a jar should be arranged parallel to one another and to the jar walls, with separators placed between the plates. The necessary clearance between the outer plates and the jar walls is pro-

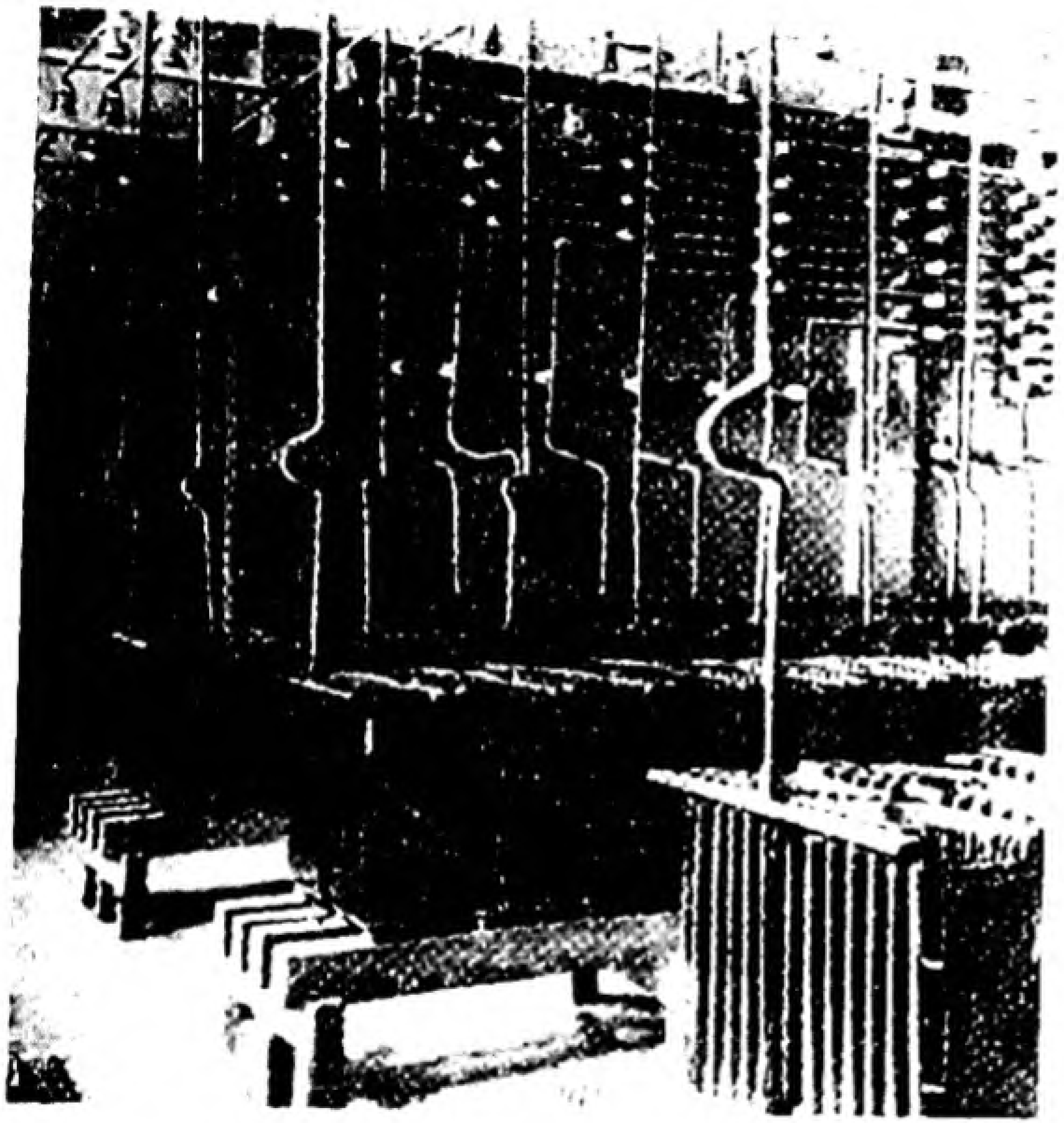
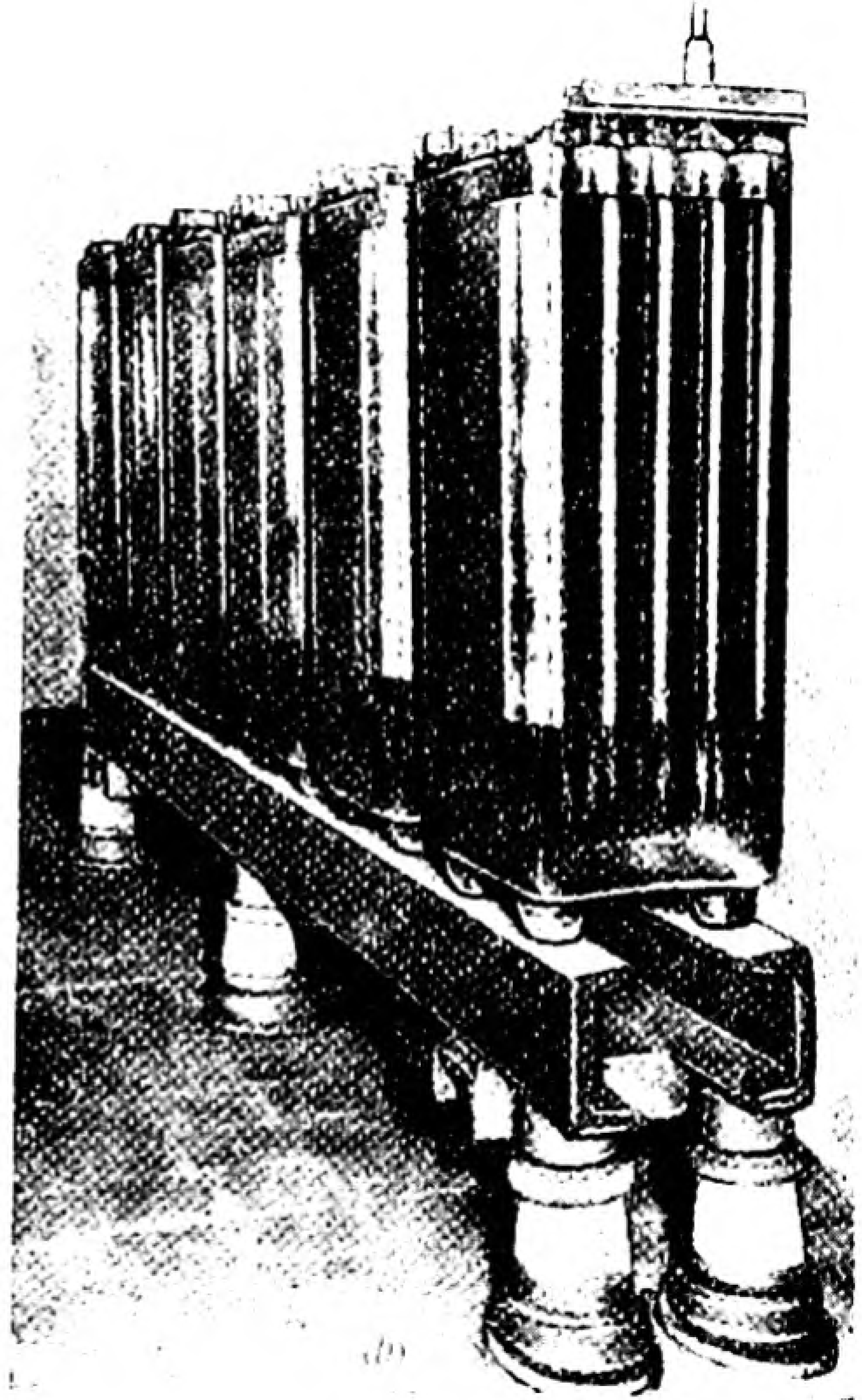


Fig. 266. View of part of a storage battery room:
a—storage batteries arranged on wooden racks; *b*—storage batteries arranged on a steel channel rack



vided by lead springs at one end, and by two rubber sleeves at the other.

The plates should be lowered into their jars with the aid of metal hooks, as fingers may be pinched if this is done with bare hands.

For connecting the separate cells into a storage battery, the plate lugs resting on the edges of the jars are burned-in to lead shoes. The lead shoe on the outer jars of each row has a boss into which a copper or steel rod is soldered for connecting one row of cells with another.

Filling of storage battery jars with electrolyte. Either ready electrolyte or concentrated sulphuric acid may be available.

Concentrated acid must be first diluted down to 23.5-26 per cent content to make up the electrolyte. The specific gravity of the electrolyte is determined with an hydrometer.

The electrolyte is prepared in special wooden vats the inner walls of which are lined with sheet lead burned-in at the joints. The surface of the lead lining should be very thoroughly cleaned.

Distilled water must first be poured into the vat, concentrated sulphuric acid added (never in opposite order!), and the electrolyte stirred with a lead rod. This must be done wearing rubber gloves, a leather apron and goggles as a protection against burns by splashed acid.

The electrolyte must be protected against dust, dirt and any foreign objects.

Ready electrolyte is poured into the jars with a ladle to at least 10 mm above the upper edges of the plates.

Installation of storage battery buses. The bus system is assembled of round copper or steel bars generally carried by support insulators and, though less often, by PCШ pin insulators (Ш for "pin", C, for "moist atmospheres"). The insulators are mounted on supports built from angles grouted in the walls of the battery room, or secured by dowels driven with a powder-actuated СМП-1 gun.

Copper and steel bars are secured to the insulators with straps or clamps of copper and galvanised steel, respectively, with lead lining used on copper bars.

Copper bars are joined by soldering, with connecting sleeves placed on the joints. Steel bars are welded. The lead bars located between adjacent cells are connected to the lugs on the plates by lead-burning.

The busbars from the battery room are brought out to the d-c board by means of an insulating slab of hard rubber or wood boiled in mineral oil. The slab has through-bolts fitted with two washers on either side. The washer placed directly against the slab surface is of lead, and the other of steel.

The installation of a storage battery is completed by measuring the insulation resistance which should be 100,000 ohms for 110-v batteries and 200,000 ohms for 220-v batteries.

The mounted storage batteries are given a forming charge, as advised by the battery manufacturer.

Problem. Draw up a sketch of an insulating slab for connecting battery room busbars with a d-c board. The bolts should be arranged in vertical and staggered pairs. A total 12 bolts 30 mm in dia may be used, spaced on 150 mm centres both between rows and in each row.

CHAPTER 7

INSTALLATION OF PROTECTIVE EARTHING SYSTEMS

46. Protective Earthing of Indoor Substations

The protective earthing system of an indoor substation is installed in two stages: first the buried outdoor earthing system is installed and then the indoor earthing buses are put in.

In the case of the buried outdoor earthing system, the trenches are laid out to the working drawing by the electricians and dug by digging crews.

The centre line of a trench should be not less than 2 to 2.5 metres from the walls of buildings, while the trench should be 0.6 to 0.7 metre deep.

While the above work is in progress, earthing electrodes are made (unless they come prepared from an outside supplier). Steel pipes of 2-inch to 2½-inch size and 2.5 to 3 metres long are used as earthing electrodes. Electrodes are usually spaced 2.5 to 3 metres apart. At the present time angle iron electrodes are also used in addition to pipes.

Electrodes are driven into the soil with a Martynov-Brodyansky hand driver (Fig. 267), an electro-vibrator driver (Fig. 268), or a truck-mounted auger fitted with an earthing-rod driving attachment.

Both pipe and angle-iron electrodes are driven into the bottom of a trench until only ends 150 to 200 mm long stick out for joining of the underground earth-continuity conductors by welding.

Underground earth-continuity conductors take the form of 40×4 mm steel strip properly straightened, laid on edge in the trenches and secured to the driven electrodes by clips first welded to the strip and then to the earthing electrodes (Fig. 269). The strength of the welded joint between an earthing electrode and an earth-continuity conductor is tested by striking it with a sledge hammer of up to 2 kg in weight.

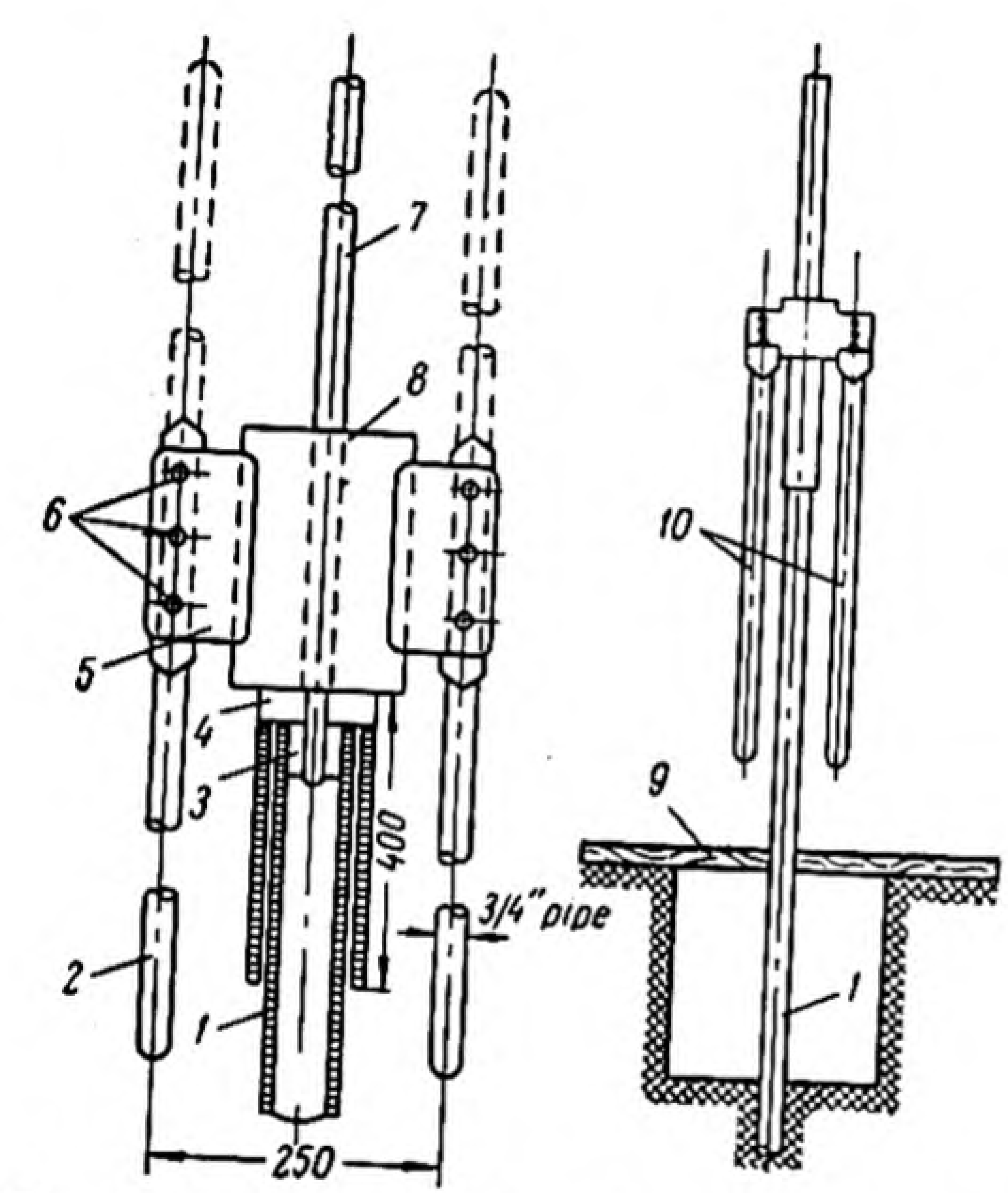


Fig 267. Martynov-Brodyansky hand driving appliance:

1—pipe earthing electrode; *2*, *10*—handle rods; *3*, *4*—capping; *5*—plate; *6*—bolts; *7*—guide rod; *8*—striking ram; *9*—board

Fig. 268. Electro-vibrator rod driver

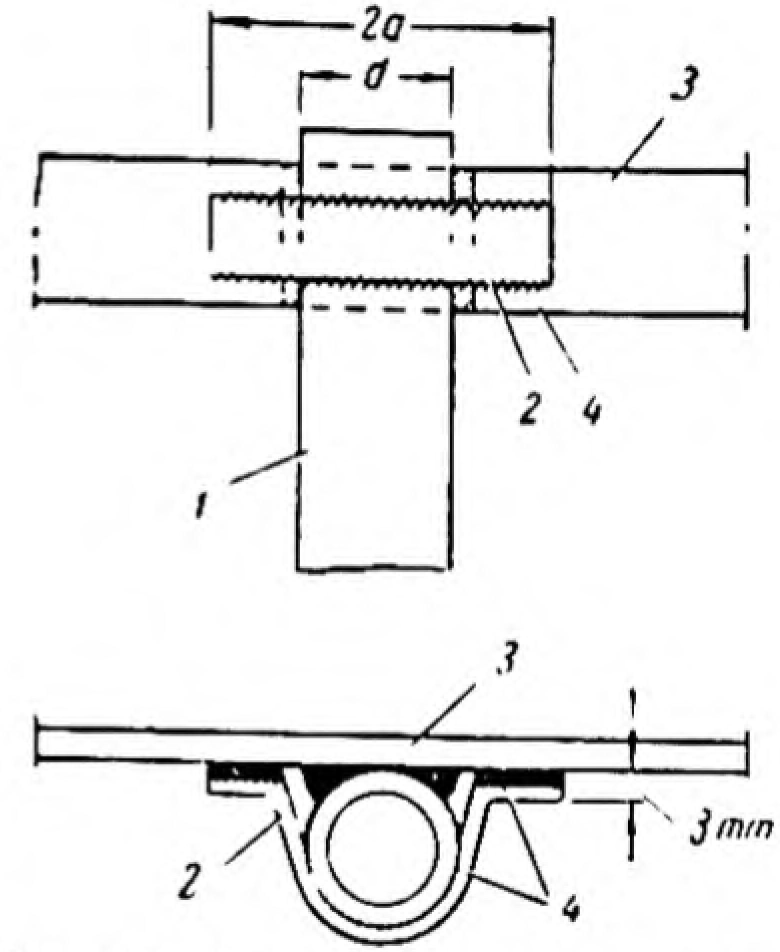


Fig. 269. Fixing of steel strip earthing conductor to pipe earthing electrode:

1—pipe electrode; *2*—loop clip; *3*—steel strip earthing conductor; *4*—weld seams; *d*—diameter of pipe

Earthing conductors are run into the switchgear structures through steel-pipe conduits.

With the outdoor earthing system in place in the trenches, all the runs of the system are drawn on a plan showing their position relative to adjacent permanent structures, the trenches are back-filled, and the soil rammed in.

Within switchgear structures the earthing buses are carried by fastenings varying in shape depending on the prevailing conditions and location and affixed to the walls and ceilings.

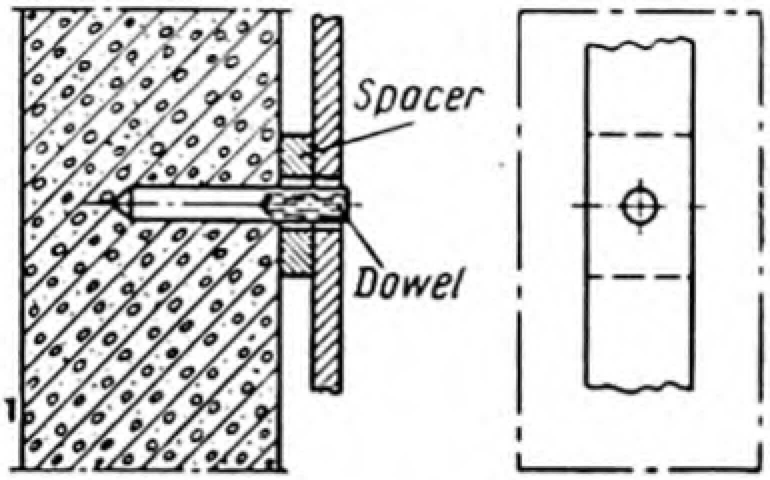


Fig. 270. Earthing bus fixed by means of СМП-1 powder-actuated gun

Earthing buses are largely fixed in place by means of СМП-1 powder-actuated gun as shown in Fig. 270.

The spacings between the fastenings which carry earthing buses indoors are given in Table 28.

Table 28

Size of earthing bus, mm	Spacing, mm
20×3	1,000
30×4	850
40×4	850
50×5	850
60×6, 80×6, 100×6	650

Where earthing buses cross temperature expansion joints, compensating bends must be provided. Where the earthing buses pass through walls, they should be run through sleeves of steel pipe.

Joints and tap-offs on earthing buses are made by welding. Runs of earthing buses to apparatus should be fastened by the earthing bolts provided on the equipment.

In the case of apparatus mounted on metal supports, the earthing conductors should be welded directly to the metalwork. The contact surfaces of the apparatus and the supports should be thoroughly cleaned and coated with petroleum jelly or grease.

The completed earthing system inside a substation is given a coat of black asphaltic varnish, while the places reserved for temporary safety earthing sets should be left unpainted.

47. Protective Earthing of Outdoor Substations

Protective earthing systems for outdoor substations consist of a buried main earthing circuit which usually has the form of a ring encompassing the entire switchyard and earth-continuity conductors radiating from the main ring towards the respective pieces of equipment.

When the main ring is large, an internal circuit is put in within about 10 metres of the main one.

The main earthing ring of an outdoor substation differs little in construction and laying procedure from the buried earthing system of an indoor substation. In both, the earthing electrodes, either of steel pipe or angle iron, are driven into the soil and then welded to a buried earth-continuity conductor.

The earth-continuity conductors which radiate from the main earthing ring to the respective pieces of equipment are generally laid in the cable trenches and welded to the inserts grouted in the walls during the construction of the trenches.

Where earth-continuity conductors are brought out to their equipment they must be enclosed in steel pipes 1 to 1.5 metres high above ground.

Problem. Write up an operation sequence for installing the buried earthing system for an indoor substation.

CHAPTER 8

ACCIDENT PREVENTION IN SWITCHGEAR INSTALLATION

48. General

Before any erection work may be started, all personnel must be briefed on general rules of accident prevention by the foreman, superintendent or engineer-in-charge, depending upon who is responsible for safety.

In addition, every worker must observe all safety regulations specific to his particular work formulated in statutory publications and in safety booklets.

Caution signs and warning boards must be posted at all places where danger may exist. All wall and floor openings must be fenced off, and ample illumination, natural or electrical must be provided throughout the premises.

Electric-driven machine tools or mechanisms should be checked for reliable earthing before use. The frames of electric hand tools must have earthing devices.

Portable lamps for voltages not higher than 36 volts should be normally used, while for work in damp locations, in circuit-breaker tanks, and on metal structures, only 12-volt lamps must be used.

Temporary electric circuits must comply with all codes and regulations for permanent wiring. Use should preferably be made of special take-down equipment for temporary electric power supply.

First-aid kits should be placed within easy reach for all personnel who should be trained to administer the principal medicines.

All personnel must know how to break an electric shock victim's contact with the source of current in the quickest safe way possible and to render him first aid, how to put out fires in electrical plant and how to use fire fighting equipment.

49. Safety Rules for Use of Hand Tools

Wooden tool handles must be made of a hardwood (beech, oak, maple, etc.), and the tools proper (hammers, sledges) securely and properly seated on their handles.

The striking faces of hammers and similar tools must have no ragged edges. Cold chisels should be at least 150 mm long, drift chisels and star drills, not less than 200 mm long.

Spanners of proper size may only be used. The use of a pipe length or of another spanner for increasing the purchase of a spanner must be discouraged.

Electric tools operating on 127 and 220 volts must always be reliably earthed and handled with rubber gloves on.

It is not permissible to operate an electric hand tool while standing on a step ladder or rung of an ordinary ladder. When necessary, scaffolds and stages should be used.

Pneumatic tools and powder-actuated dowel guns may only be used by competent personnel.

50. Safety Rules for Hoisting

Before hoisting any piece of equipment, all hoisting facilities must be checked for possible defects. Ropes must have no breaks and be of appropriate size for the weights to be handled. The splices of loops at rope ends should be at least 25 rope diameters long, or the loop should be made with at least three bolt clamps.

Wire ropes should be free from kinks. Ropes to be used with pulley blocks should never be spliced or have any defects.

Slings may be attached to a weight only where it is allowed to. When long pieces of equipment are to be lifted, at least two slings and a spreader or lifting beam should be used.

Electrical equipment must be hoisted only by the lifting lugs and eye-bolts provided for this purpose. When the equipment to be lifted has sharp edges, special wooden or metal paddings should be placed under the slings so that they will not drop out when the load is being hoisted or lowered.

No one should be allowed to stand under a load being lifted by a crane, hoist or boom.

Nobody should be allowed to adjust the lifting hitch or touch the lifting cables or ropes during the lifting of a load.

The lifting hook may only be disengaged after the load is fully lowered, reliably seated and secured.

Hoisting personnel must be well versed in the appropriate signals and commands.

51. Safety Rules for the Installation of Main Electrical Equipment

Where equipment has to be set up at a height of greater than four metres, use should be made of scaffoldings and stages provided with railings one metre high and floor toe boards to prevent tools from falling.

Pieces of equipment up to 20 kg in weight should be lifted in place and mounted by two workmen. Heavier apparatus should be handled with block and tackle or chain hoists when installing it indoors, and with portable booms and truck cranes in outdoor substations.

Prior to installation of equipment, the supporting structures and fastenings should be checked for reliable fixation and strength.

Isolator blades and the tie rods between an isolator and its operating mechanism should be adjusted by an electrician and his mate working in concord in order to avoid injury to their arms by the moving parts of the apparatus.

Special care must be exercised when the blades of BH-16 load-breaker isolators are being adjusted. Lack of attention or failure to work in concord during trial operations may result in serious injury to the man adjusting the contacts.

Circuit breakers may be moved only when they are in the closed position. The temporary latch holding a breaker in the closed position should be released with the aid of the operating mechanism by performing the opening operation slowly.

When adjusting tie rods and contacts, the electrician and his mate must work in agreement in order to avoid having their hands caught.

Before closing or opening a breaker by remote control, the temporary manual operating lever should be removed.

It is dangerous to be inside a circuit-breaker tank, stick one's head into it, or touch any moving parts of a circuit breaker when the latter is operated manually or by its operating mechanism.

CHAPTER 9

ERECTION OF OVERHEAD POWER LINES

52. Elements of Overhead Lines and Erection Procedure

Classification and elements of overhead power lines. Overhead lines are circuits which transmit electric power from a source of power generation to a point of power consumption.

By purpose and working voltage, transmission lines are classed in the Soviet Union into four main groups.

The first group comprises long-distance lines with a working voltage of 400 to 500 kv which transmit power from large power stations to individual or interconnected power systems.

The second group embraces block power transmission lines with a voltage of 220 kv which interconnect separate systems and also supply power to large industrial regions.

Within the third group fall 110-kv transmission lines which supply main switching stations and also interconnect them within a given power system.

The fourth group consists of distribution lines with voltages of 110 kv and 35 kv which supply power to industrial loads or groups of industrial loads in a given district.

This book deals with the third and fourth groups of power lines.

The main elements of an overhead line are the line supports and their foundations, insulators, line accessories, conductors, and overhead earth-wires (Fig. 271).

Line supports can be built from wood, reinforced concrete, and metal. By function, they are classed into intermediate supports which carry the load due to the conductors and insulators, and anchor supports which take the entire tension due to all the conductors and overhead earth-wires.

Supports at the ends of a line are called terminal supports and supports placed where angle turns occur in a line are termed angle

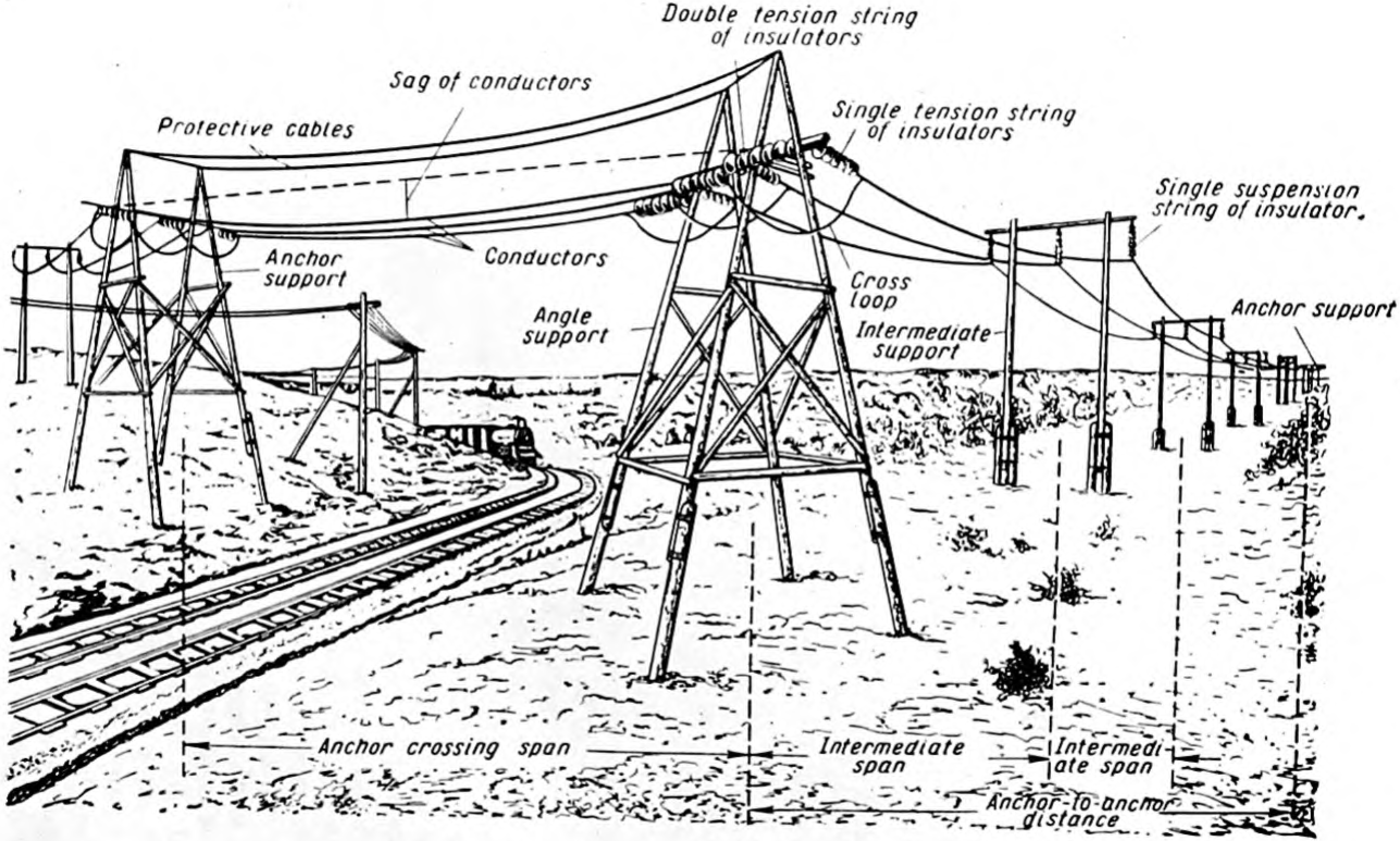


Fig. 271. Main elements of an overhead power line

supports. Terminal supports must carry the one-sided tension due to the conductors and earth-wires.

The part of a support buried in the soil is called the footing or foundation. For wood pole supports the footings may be reinforced-concrete or wood-pole stubs set in the soil, or driven like piles. For reinforced-concrete and metal poles the footings or foundations may be reinforced-concrete piles, prefabricated reinforced-concrete members, or poured-in-situ concrete or reinforced-concrete foundations.

Conductors for 35- and 110-kv overhead lines are generally aluminium and steel-cored aluminium. The conductors are carried by strings of suspension insulators. Details of these conductors and insulators are given in Sec. 37.

Line erection procedure. Before a transmission line can be erected, maps and profiles of the line route, a pole setting schedule, working drawings, and bills of the requisite materials and equipment are prepared.

In addition, plans are included for the construction of auxiliary facilities as linemen's huts, bridges, dispatcher communication lines, etc.

The way-leave for the line must be obtained from the organisations whose holdings and facilities they intersect (railway, river transport, telephone and other services).

In the Soviet Union lines are erected by specialised organisations. Such organisations have each a number of district offices to which field offices report. Short 110-kv lines, as well as all 35-kv lines, are erected by field construction sections reporting to their field offices.

Line erection includes:

(a) preparation for line construction which covers locating and laying out the line, clearing work, and erection of the necessary structures and services;

(b) line construction which covers delivery of line supports, conductors and insulators to their sites, their assembly and erection.

53. Support Erection

Wood-pole support erection. In most cases wood-pole supports are erected by a falling derrick pole method. The derrick pole may be made of wood poles or metal. Wood poles are used more often because they have a relatively small weight, are cheaper to make and more convenient to transport.

Derrick poles longer than 10 metres are made from metal, as wood poles would have to be joined together from several logs, which is an obvious inconvenience. Let us consider the erection of an H-type wood-pole support with a falling derrick pole of wood (Fig. 272).

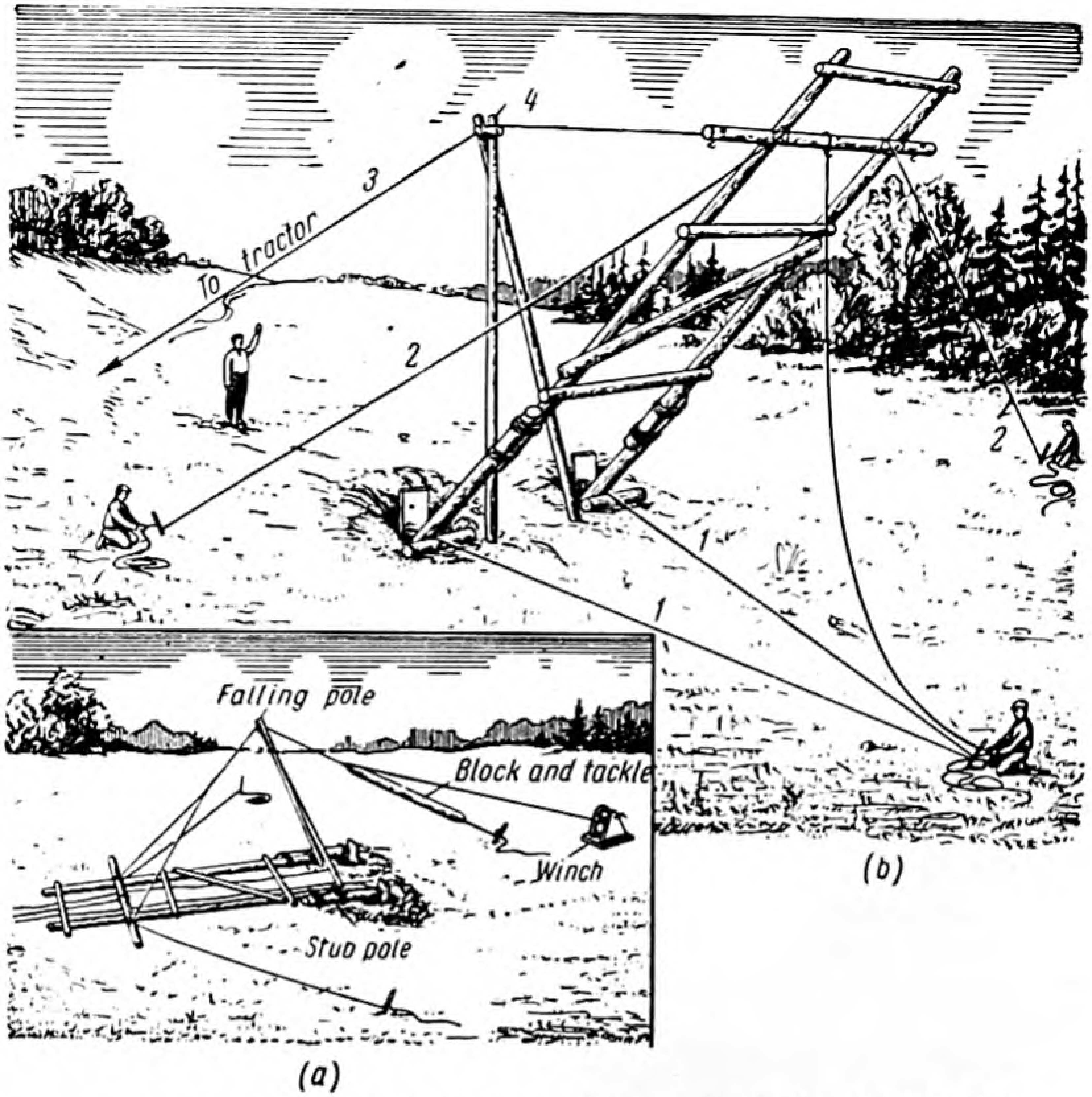


Fig. 272. Erection of H-shaped wood pole support with a derrick pole:
a—by a winch and block and tackle; *b*—with use of a tractor

The pole supports are laid out along the line route so that their stub-pole footings are just above the ready holes in the soil. A derrick pole *4* is placed so that its legs are within 1 to 1.5 metres of the holes and between the stub poles. Two side pulling ropes connecting the pole with the support and a raising line *3* run to a winch are attached to the top of the derrick pole. Two more ropes *1* are made fast to the stubs to prevent the support from being dragged in the direction of the pull.

The derrick pole is raised into position by means of so-called shoring poles consisting of two round baulks each 3.5 to 4 metres long and resembling a derrick pole but of smaller size.

To allow the support to turn easily when the lifting is started, two short round logs are placed under the stub poles.

To prevent the support from moving sidewards in raising, two guy ropes *2* are tied on both sides and attached to temporary anchors driven into the soil. The walls of the pole holes are covered by boards as a protection against being caved in by the pole legs when the support is being raised.

The pull can be provided either by block and tackle and a winch, or a truck, or even better, a tractor.

When the support has reached an angle of about 35 to 40 degrees, the lower braking ropes are slowly paid out.

As soon as the support slips into the pole holes, the derrick pole becomes inoperative. To prevent it from falling, it should be tied in to the support by a back rope in advance.

When the support reaches a vertical position, the lower braking ropes are no longer necessary. The upper holding line attached to the middle of the cross-arm now comes into action (see Fig. 272*b*).

The support is then plumbed and adjusted, if necessary, by means of the pulling and holding lines and the side-guy lines.

The pole holes are now back-filled in layers, taking care to ram the earth in one layer at a time, and the tackle may be taken down.

Fig. 273 shows how an AH-type wood-pole support is erected by the same method.

Wood-pole supports can also be erected by a truck crane. The support is laid along the line route with its stub-poles just above their holes. The crane is manoeuvred along the line and behind the pole holes. The crane hook is secured to the X-braces of the support with a length of rope (Fig. 274).

As the support is raised, its stub poles slide into the pole holes. The crane, at the same time, moves forward along the line.

When the support is set up vertically, it is plumbed and aligned, and the pole holes are back-filled while ramming one layer of earth after another.

If the support is out of the vertical, it must first be straightened by removing the soil from under its higher leg or by pushing a short baulk under the lower leg, raising the legs with a jack.

Erection of reinforced-concrete poles. Reinforced-concrete poles are best erected with the use of a derrick pole (Fig. 275) and a tractor as the source of pull.

The derrick pole is tied in to the upper and lower cross-arms or brackets of the support pole and is placed above the support within about 1.5 to 2 metres of the pole butt. Where the ropes are tied to the support, the concrete should be protected by short pieces of hardwood.

Back lines are unnecessary in this case because the butt of the support, as it slips into the pole hole, is immediately brought up against the wall of the hole.

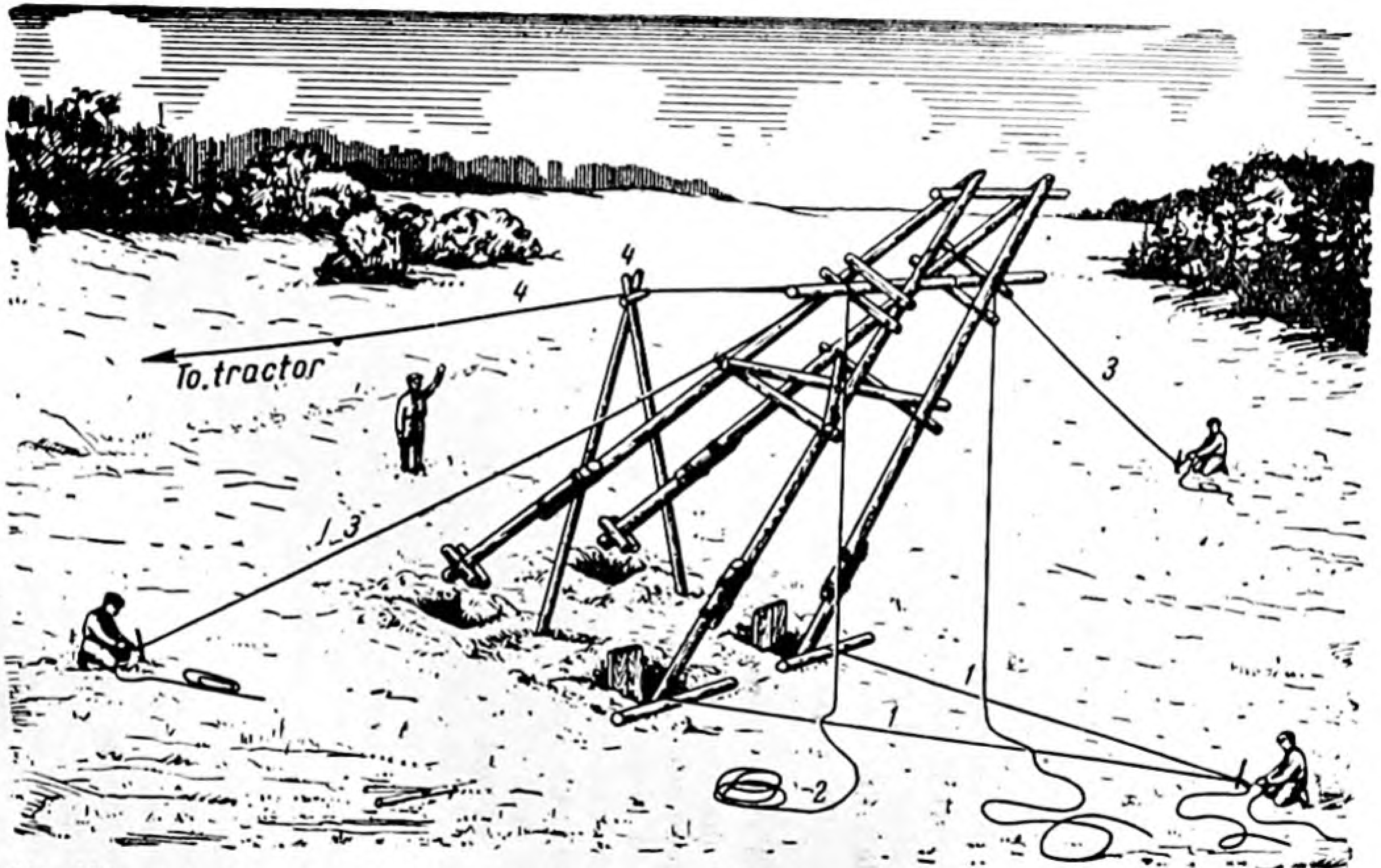


Fig. 273. Erection of an AH-type wood pole support with a derrick pole; *1, 2, 3, 4*—wire ropes

The pole is set up vertically by means of the raising line and the side-guys.

Reinforced-concrete supports may also be erected with cranes (Fig. 276), for which purpose a support is first lifted by a crane, and then lowered into the pole hole in the vertical position. The pole is plumbed and aligned, the hole back-filled and the soil rammed in much as in the previous case.

Safety rules for support erection. Good hoisting facilities go a long way toward complete safety in support erection. The winches,

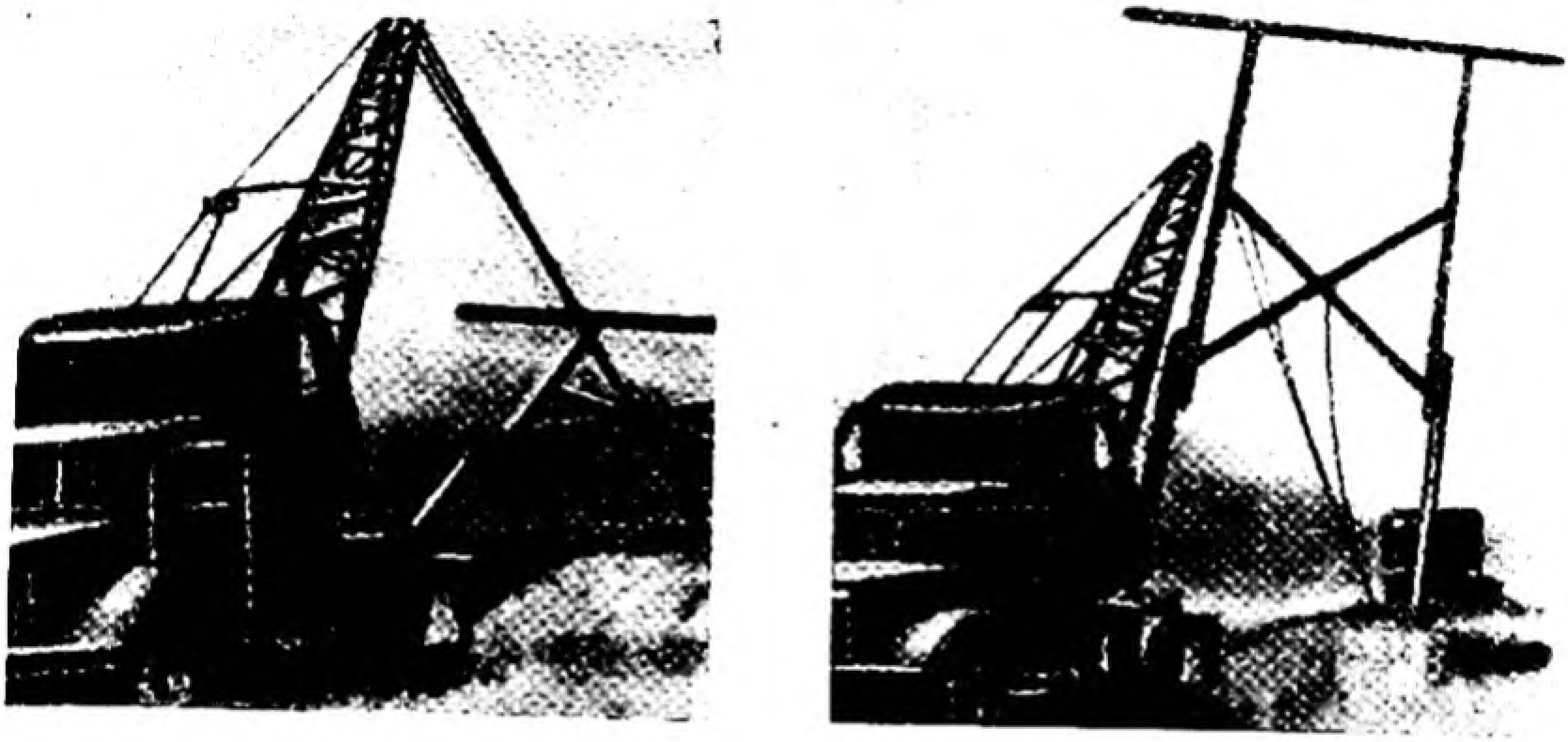


Fig. 274. Erection of H-type wood-pole support with a mobile crane

pulley blocks, etc., should be registered as required by law and have special log-books in which their annual inspections and tests are recorded and signed.

All machinery used for handling heavy weights should bear the date of the last inspection test, stenciled with a durable paint or stamped with a die.

Before any work is commenced, all the tackle, irrespective of the date of the last test, must be inspected for cracks on the hooks and worn shaft pins of pulley blocks, and for damaged strands in the ropes.

Under no circumstances may defective tackle be used.

Prior to pole erection, the back lines and guy ropes should be checked for reliable fixation, as should the raising lines for attachment to the support and to the crane or tractor.

Special attention should be paid to the condition and setting-up of derrick poles. For a more uniform distribution of pressure on the soil, timbers or heavy boards should be placed under the legs.

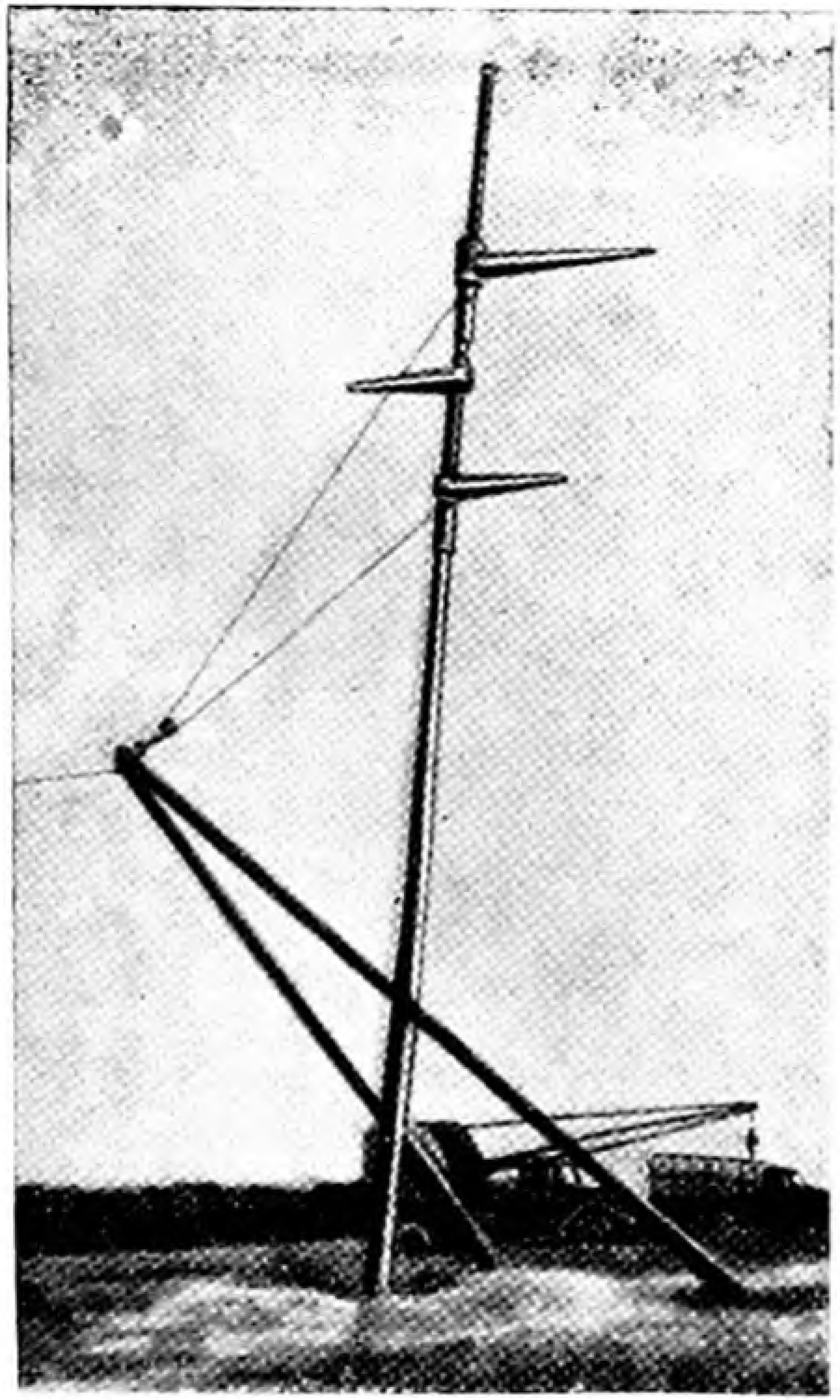


Fig. 275. Erection of a reinforced-concrete pole with a derrick pole

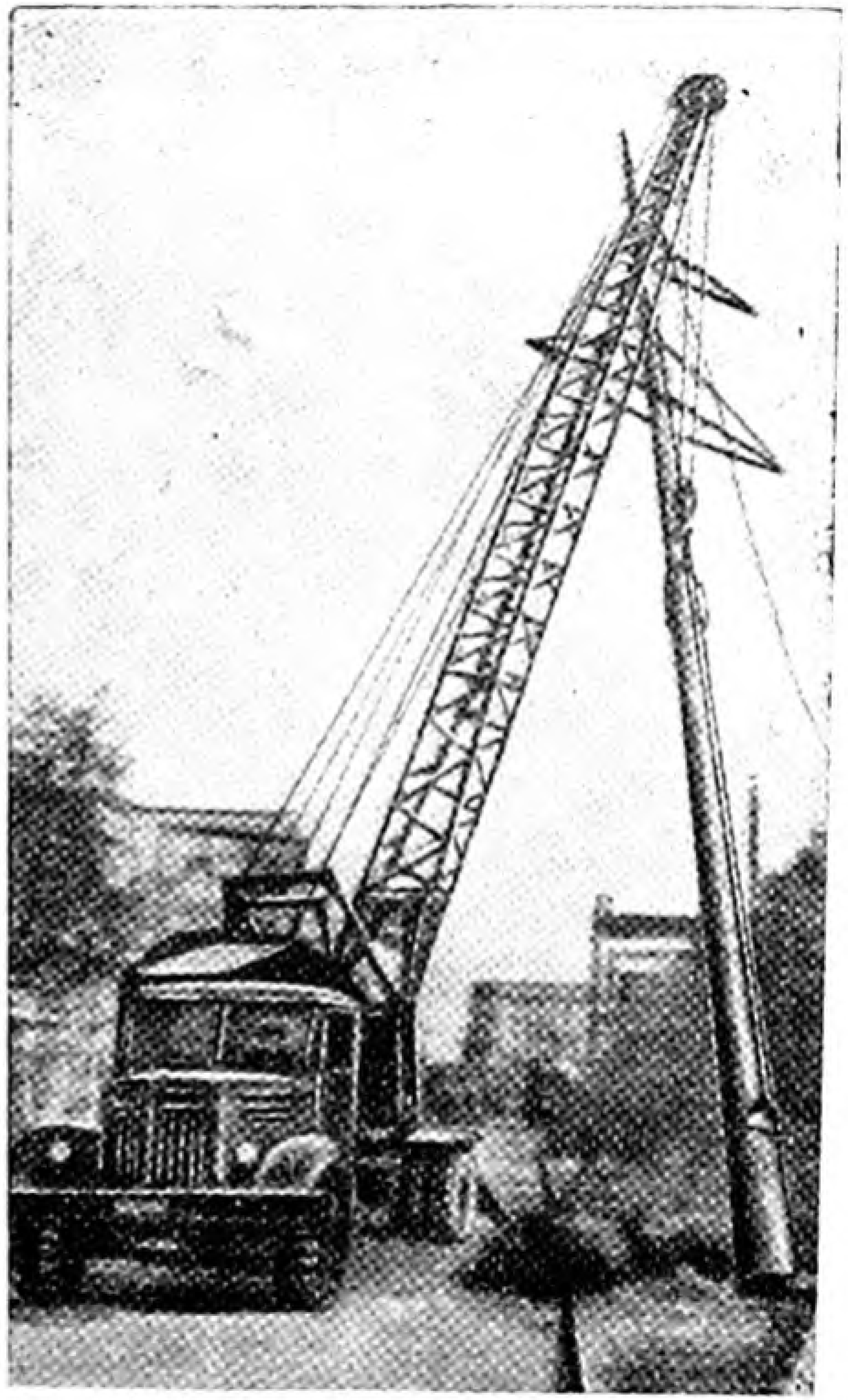


Fig. 276. Erection of a reinforced-concrete pole with a mobile crane

When a support is being raised, no one of the erection crew should find himself under the support, under the tensioned ropes, in a pole hole, or where the support or derrick pole may fall. Every man in the crew should be at his work station and within sight of the crew leader.

As soon as a support is set up, it must be guyed, and a watchman should be left at supports which are temporarily guyed.

A support may be climbed only after it has been fully anchored. When a support is being raised, or anchored, no one should be allowed to stand under or near it, as dangerous accidents may result from the fall of a tool, tackle parts, etc.

54. Installation of Conductors and Earth-wires

Running-out operations. Conductors and earth-wires can be taken to the erection site on trucks, horse-drawn carts or tractor-drawn trailers. In loading, transit and unloading, cable drums should be protected against injury. Hence, cable drums must be snugly held in place in the body of the vehicle by wedges and ropes. Cable drums should never be dropped and may be rolled only as indicated by the arrow on the drum side.

The drums should be distributed along the route at distances approximately equal to the length of the conductor or wire wound on the drum.

Insulators for the conductors are taken to the locations packed in boxes or special crates, or in some cases, unpacked and bedded in straw or hay. The number of insulators left at each support should take into account possible breakage.

The boxes containing the line fittings are stored in the watchman's hut on the line and handed out when required.

Prior to running out a conductor or overhead earth-wire, a spindle should be passed through the drum and the drum raised on a running-out support. The conductor or earth-wire is run out by rotating the drum on the spindle. When the conductors or earth-wire come wound in coils, they are run out on vertical stands.

In both cases the drums and coils remain stationary, and the conductor or cable is pulled by hand, horse, or tractor. Alternatively, the drum may be placed on a truck from which the conductor or earth-wire is paid out as the truck moves along the line.

As the conductor or cable is run out, it is passed through the gloved hands and examined for defects or damage by feel. When a defect is spotted, running-out is discontinued, and the faulty section is either cut out or repaired.

The conductor is run out by pulling it over the ground or over snatch blocks. The second method is preferable as the conductors are less likely to be damaged and a smaller pull is required. By the second method, as a support is approached, the conductor is passed over snatch block (Fig. 277) made fast to an assembled suspension insulator string on the support, and the conductor is run to the next support.

The insulator string and the snatch block (Fig. 278) are suspended at some height from the corresponding cross-arm of the support by means of a rope passed over a block.

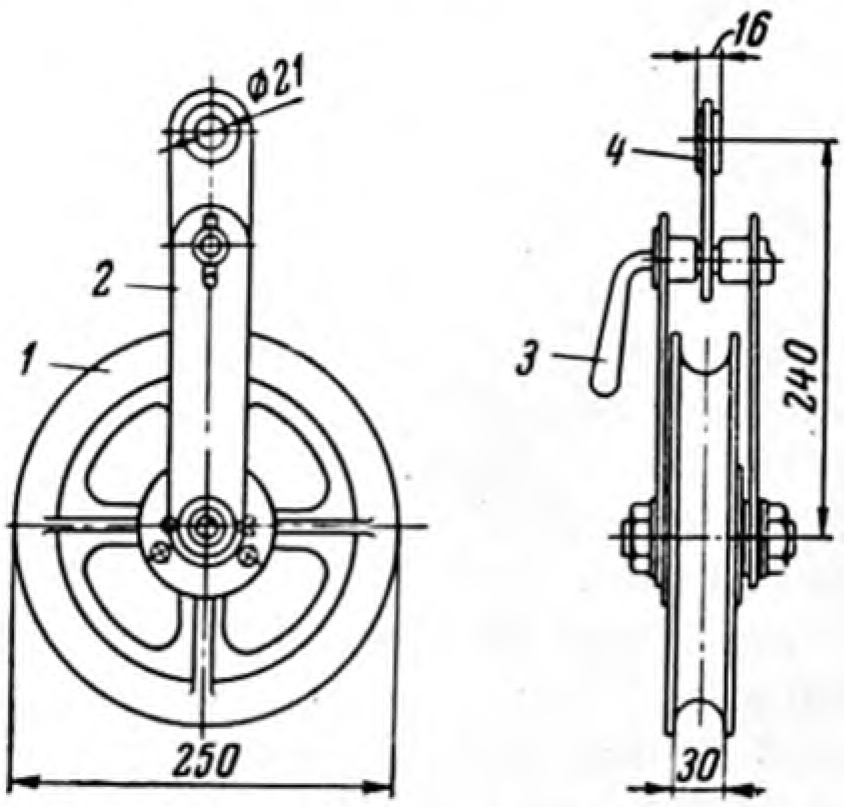


Fig. 277. Snatch block:

1—sheave; 2—two cheeks; 3—lock and handle for opening cheek to insert conductor; 4—suspension link

When insulator strings are being assembled, the porcelain should be inspected for breakage, chipped spots, cracks, scratches, and bare unglazed areas. The insulator fittings should also be inspected for cracks, laminations, damaged galvanised coatings and poor articulation. Damaged spots on the galvanised coating and paintwork should be touch-painted. Parts which cannot be remedied must be rejected and replaced.

All the insulator units in an assembled string should have locks in the caps and also engaging eyes. The locks should be arranged so that they are on one line down the entire insulator string. Before assembly, the insulators should be cleaned to remove paper labels, and washed with warm water to remove dust and dirt.

Conductors and earth-wires are run out with the aid of comealong clamps or grips attached to the pulled end of the conductor. The clamps should suit the grade of conductor. Thus, wedge-type come-

along clamps are used for copper conductors; for aluminium conductors wooden or aluminium bolted clamps are used.

Where conductors and earth-wires must be strung across roads, railways and the like, or over electric lines (only up to a working voltage of 1,000 v), derricks or ladders or ropes must be used to prevent interference with normal operation of these services.

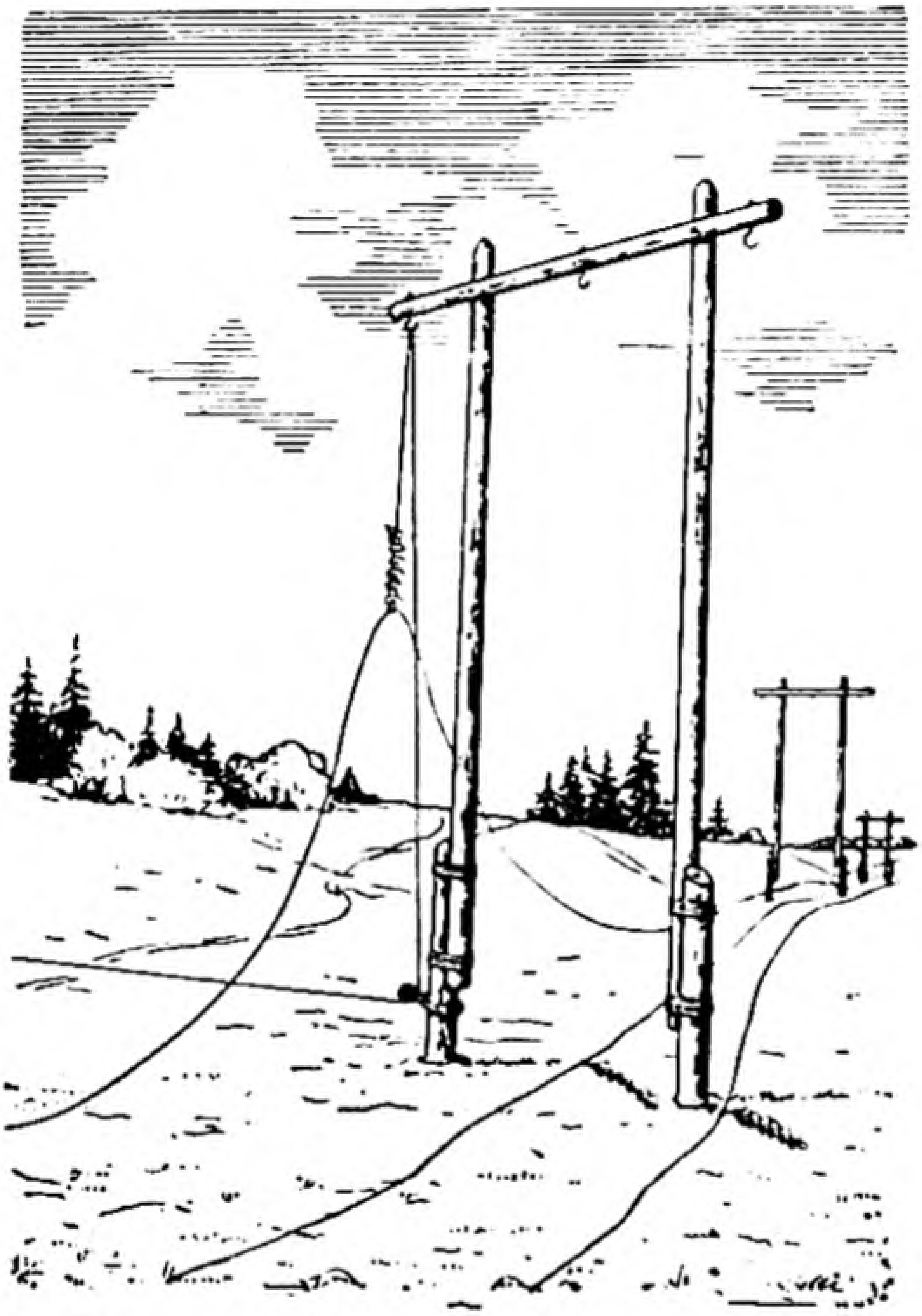


Fig. 278. Temporarily raised string of insulators and conductor at a line support

Where conductors have to be run out across country roads, they are frequently laid for the time being in narrow ditches dug across the road and covered by boards. Electric power lines must be de-energised until the work is done.

Before strings of insulators are lifted into place, the conductors are checked to make sure that they have been laid on the ground as they will be arranged on the supports. The insulator strings are again

inspected for possible damage and proper assembly. The stringing block is also checked for proper functioning and the position of the conductor or wire passed over it.

As was stated earlier, insulator strings and stringing blocks are lifted with a rope passed over a snatch block attached to a support cross-arm. The end of this lifting rope is tied to the string between the first and second insulator units from the top.

It is good practice to use for lifting a special clamp which is attached to the second insulator from the top of a string (Fig. 279). To

Fig. 279 Clamp used for lifting strings of insulators

avoid damage to the glazing, the clamp should be lined with leather or rubber.

The other end of the lifting rope is passed through the block secured at the bottom of the support (see Fig. 278) and is taken to a winch, tractor, or truck. After the string has been lifted to a height of 1 to 1.5 metres, it is again checked and then lifted up to the cross-arm where it is fastened with a shackle to the suspension fitting on the cross-arm. Care must be taken to lock the shackle with a cotter-pin.

Where the conductors are arranged on the supports vertically, the upper conductor is the first to be lifted. In lifting, a workman should be stationed on the third cross-arm from the top to push the string and conductor clear of the lowest cross-arm and then of the middle cross-arm. The middle conductor is passed clear of the lowest cross-arm in a similar way.

Earth-wires, if used, are raised on separate stringing blocks prior to lifting of the line conductors. Fig. 280 shows how an earth-wire is anchored to a wood-pole support.

Conductor jointing. Conductors are jointed after they have been run out along the line. A joint should develop 90% of the strength of

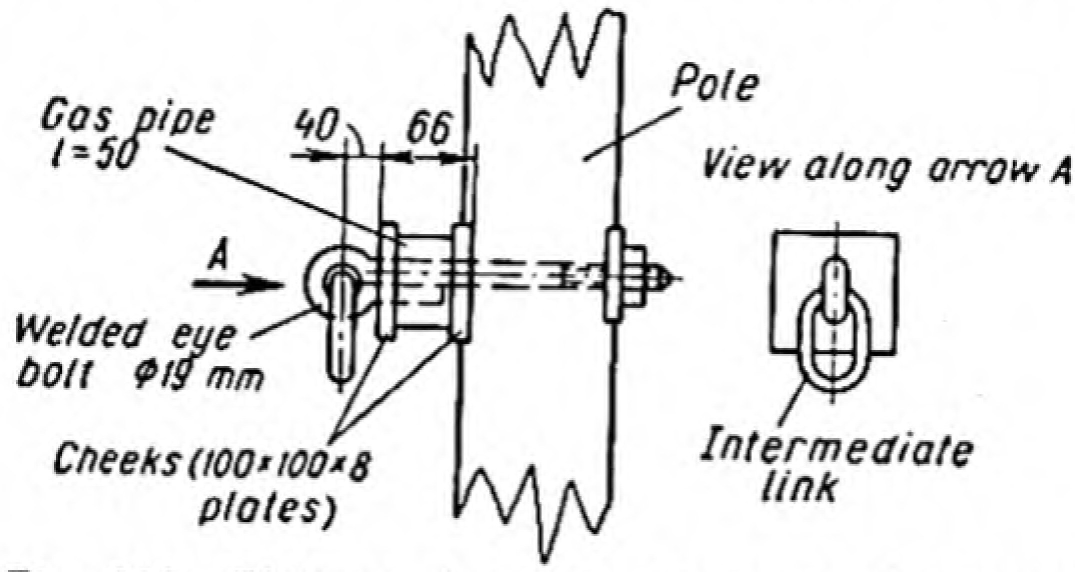


Fig. 280. Fittings for securing an earth-wire to wood-pole support

the conductor. The electrical resistance of a joint should not exceed that of an equal length of the conductor, while the temperature rise of the connector mounted on a conductor should not exceed that of the conductor proper when the maximum current for the given conductor flows through the joint.

The two methods mainly used for jointing conductors are based on indentation and compression. Indentation joints are used on copper, aluminium and steel-core aluminium conductors in sizes up to 240 sq mm; compression joints on extra-strength ACУ steel-cored aluminium and general-purpose steel-cored aluminium conductors of 300 and 400 sq mm size. Compression joints are also used on hollow copper conductors and steel earth-wire of 50 sq mm and greater size.

Indentation joints. These joints require a portable screw press like the one shown in Fig. 281 and dies. The press consists of two lever arms *1* and *2* hinged by a pivot *3*, and of a stirrup *7* hinged to stationary lever arm *2* by a pin *4*. The stirrup has an internal thread *6* into which a bolt *5* is screwed by a two-arm handle *8* during jointing. The press is furnished with assorted dies *9*, each size consisting of an upper and lower die. These dies are secured in die seats *11*. The screw *10* serves to adjust the degree of compression.

Each die pair is marked with numbers corresponding to the size of conductor for which the pair is to be used, while both dies in a pair have similar ordinal numbers.

After use, the dies must be removed, washed in petrol or kerosene, coated with petroleum jelly and wrapped in heavy paper. The press

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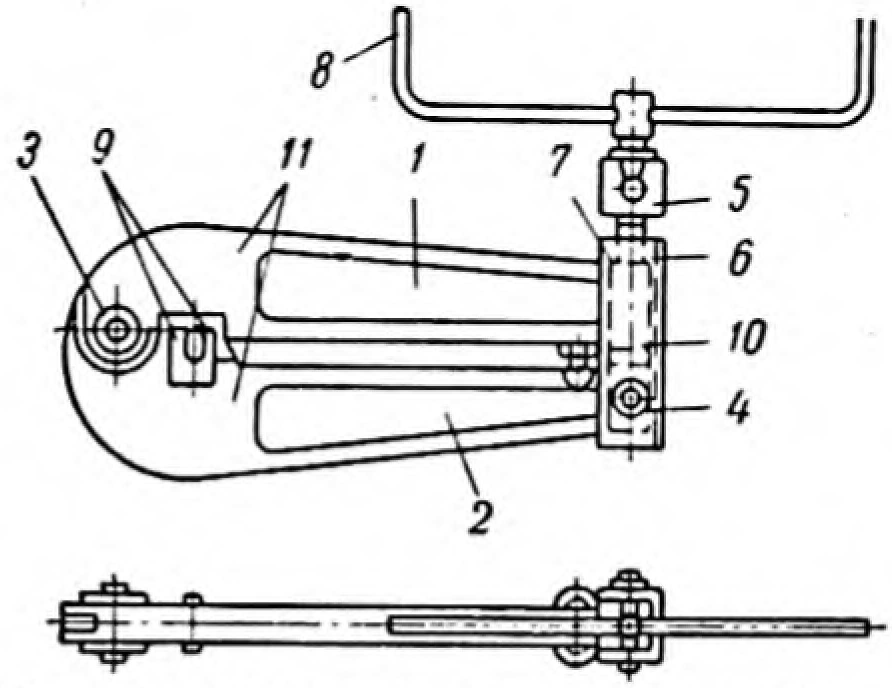


Fig. 281. Screw press for jointing conductors by indentation of jointing sleeves

should be given a coat of machine oil. Both the press and the dies should be stored in a dry place.

Before jointing, the conductors should be first checked to see that they are arranged on the ground exactly as they should be strung on the support. Servings of soft wire are applied to prevent the conductor strands from loosening, and the ends to be joined are cut square with a hacksaw or in the press itself by putting in paired cutting dies. The ends are then cleaned for a length of 1.3 to 1.5 times their length in the jointing sleeve. In the case of a heavily oxidised conductor, each strand is unravelled and cleaned separately.

The conductor to be cleaned is first wiped with a dry rag, then with a rag wetted with petrol and is finally wiped dry. The ends are given a thick coat of petroleum jelly or protective paste and cleaned with a steel-wire brush. The same treatment is given to the internal surfaces of the sleeve, the only difference being that a steel-wire tube brush is used.

The protective paste consists of petroleum jelly to protect the contact surface from oxidation, and zinc powder, which, being harder than aluminium, becomes imbedded in the conductor material and provides, as it does, contact bridges within the joint over its entire length. A protective paste has recently been developed in which the zinc powder has been replaced by quartz sand.

The dies *9* and the oval sleeve are then checked to see whether their size or diameter is the same as that of the conductors to be jointed. The dies are put in place, watching that the letters and numbers on them are on the same side.

A clearance of 0.4 to 0.5 mm is set between the dies by means of the screw *10*. The clearance can be checked with a feeler gauge. The conductors to be jointed are pushed into the sleeve from the opposite ends, until they project about 15 to 20 mm beyond the ends of the

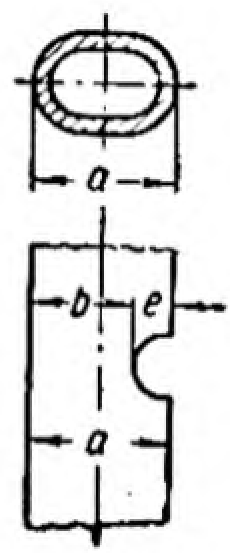
sleeve. The scribe marks on the edges of the sleeves should be on the side of the outgoing conductors.

The sleeve, with the conductors pushed into it, is placed between the dies and indented by turning the two-arm handle *8*. Each time the lever arm *1* touches the screw, the joint should be left clamped between the dies for 1 or 1½ minutes. The indentations on the ready joint are then checked for proper depth against Table 29.

Table 29

Depth of Indentations on Oval Jointing Sleeves for Aluminium and Steel-cored Aluminium Conductors

Conductor size, sq mm	Depth, mm					
	Grade A aluminium wire			Grade AC steel-cored aluminium wire		
	a	b	e	a	b	e
16	15.4	10.5	4.9	—	—	—
25	15.4	12.5	5.3	—	—	—
35	20.4	14.0	6.4	23.2	17.5	5.7
50	23.4	16.5	6.9	26.6	20.5	6.1
70	26.6	19.5	7.1	31.2	25.0	6.2
95	30.2	23.0	7.2	36.2	29.0	7.2
120	34.0	26.0	8.0	41.2	33.0	8.2
150	38.0	30.0	8.0	45.2	36.0	9.2
185	42.0	33.5	8.5	49.8	39.0	10.8
240	—	—	—	55.8	43.0	12.8



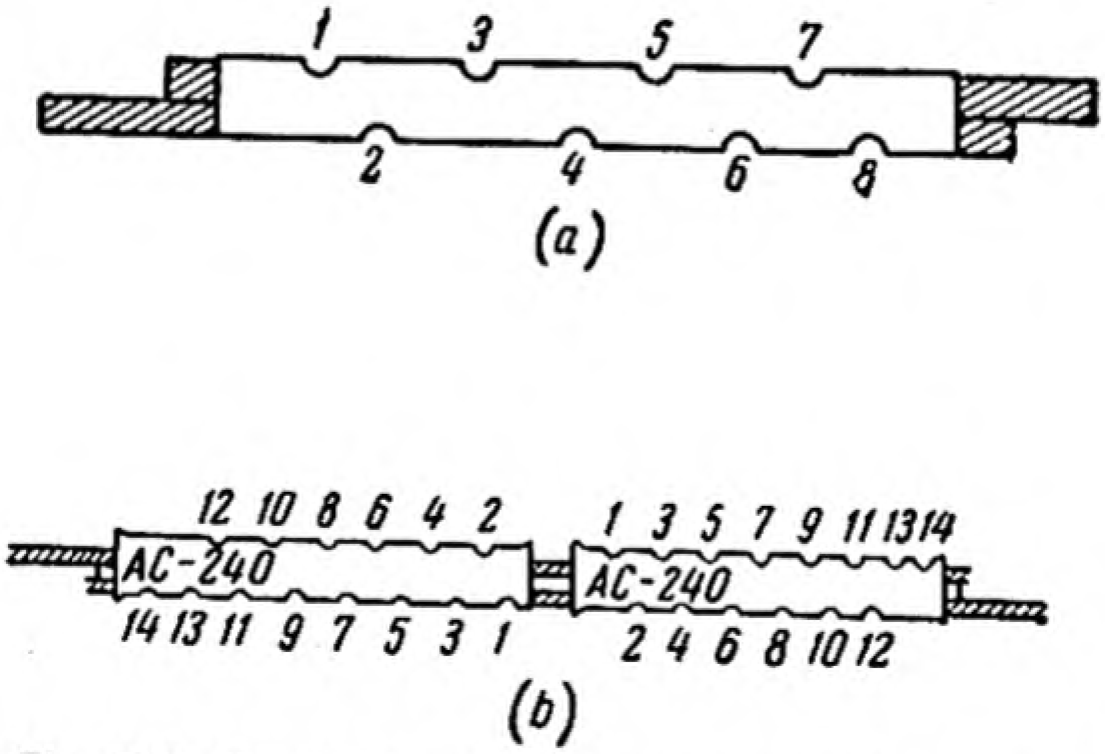


Fig 282. Conductors jointed by indented sleeves:
a—with one sleeve; *b*—with two sleeves

The joint is made beginning at one end and working out towards the other end in a staggered sequence, doing the indenting at the scratch marks on the sleeve as shown in Fig. 282*a*.

The number of indentations on the sleeve varies with the size of the conductor and can be determined from Table 30.

Table 30

Size of Grade A aluminium wire, sq mm	Number of indentations	Size of Grade AC steel-cored aluminium wire, sq mm	Number of indentations
16-35	6	35	14
50-70	8	50,70	16
95-185	10	95	20
240	12	120,150	24
—	—	185	26
—	—	240	2×14

On steel-cored aluminium conductors, the joint is made beginning at the centre of the joint sleeve and working out towards each end.

A similar joint but using two sleeves is used on Grade AC steel-cored aluminium conductors of 240 sq mm cross-sectional area or greater (Fig. 282*b*).

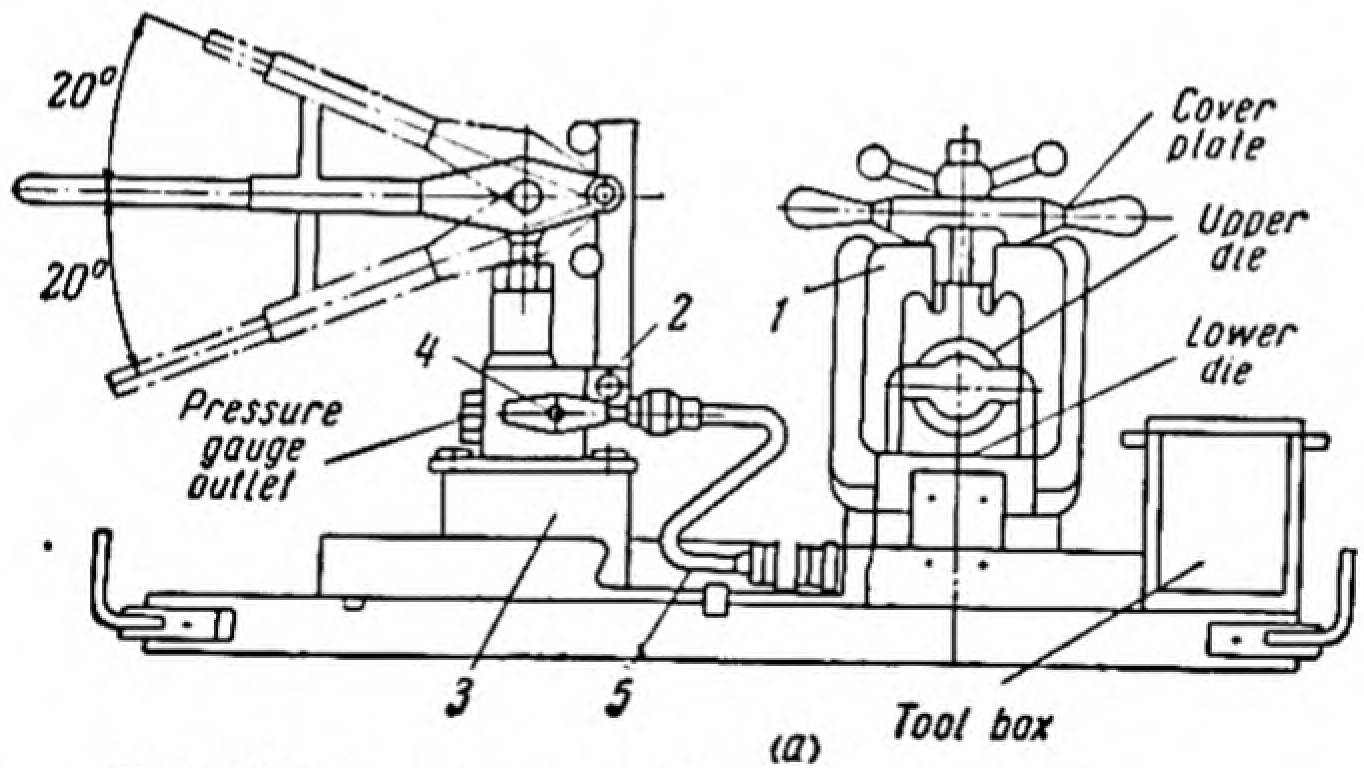
Compression joints. These joints require a hydraulic press unit and dies (Fig. 283*a*). The unit consists of a hydraulic press *1* with a piston 120 mm in diameter in which the lower die is placed, a hand-operated hydraulic pump *2* having a 12-mm diameter plunger, and a suction and a delivery ball valve, a tank *3* containing the working fluid (2.3 litres of spindle oil), a valve *4* to discharge the working fluid from the press back into the tank, and piping *5* between the press and the pump.

When much work has to be done, a mechanised unit (Fig. 283*b*), built on the same principles and powered from the engine of a truck is used.

The press in each unit has assorted dies marked in pairs for a particular size of conductor. In addition, each pair is stamped with its own sequence number.

Sleeves are made from aluminium for use over the aluminium strands and from steel for use on the steel core.

Before jointing, the conductors to be joined are arranged as they should be strung on the support, the ends are cut square, cleaned, etc. The bore and length of the jointing sleeve should also be checked against the working drawings. The tolerances are ±5.0 mm on the



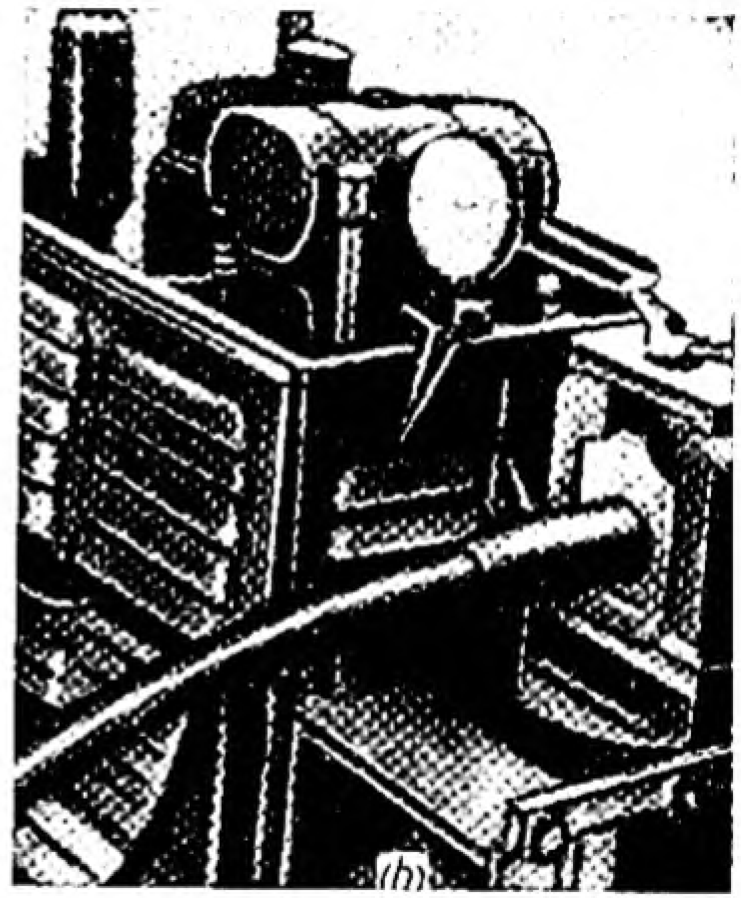


Fig. 283. Compression jointing unit for conductors:
a—hand-powered unit; b—power-operated unit

length of the sleeves, ± 0.5 mm on their inside diameter, ± 0.5 mm across the large axis and ± 0.2 mm across the small axis.

The conductor ends and the sleeve are thoroughly cleaned and coated with an anticorrosion compound.

Servings of wire (B_1 in Fig. 284*a*) are applied, the aluminium sleeve is slipped on, say, the right-hand cable end, the wire serving B_1 is loosened and backed out of the way beyond the sleeve, and another serving of wire B_2 is applied to the end of the conductor projecting from the sleeve (Fig. 284*b*). The first serving B_1 is removed, and the sleeve is backed about 0.8 to 1 metre from the conductor end.

Servings of wire B_3 are then applied some six-tenths of steel sleeve length L (Fig. 284*c*) from the end of each conductor, the servings B_1 and B_2 are removed, the aluminium strands are spread, cut to half their thickness, and broken off. Now servings of wire B_4 are applied to the ends of the steel core bared for the length E in Fig. 284*d*. The steel core ends are de-burred, cleaned with petrol, and given a coat of an anticorrosion compound. The steel core is pushed into the steel sleeve, with the servings B_4 removed.

The steel sleeve, with the conductors pushed into it, is mounted on the lower die so that the working face of the latter is at the centre of the joint and the flutes on the steel sleeve sides are vertical in respect to the die base. The upper die is put on, and the entire assembly is placed in the press, with the piston in its lowest position. The steel joint is compressed beginning at the centre and working out towards each end. The joint should be moved each time so that each fresh grip overlaps the previous one by 6 to 8 mm.

On each grip the dies should be brought within 0.1 to 0.3 mm of each other, checking this clearance with a feeler gauge.

Should the sleeve be curved by compression, it can be straightened by turning the lower die through 180 degrees, with the concave side facing downward.

After compression, all possible burrs and high spots are removed with a file, and the joint is given a coat of petroleum jelly.

The aluminium sleeve already slipped over the conductor is then compressed. For this, it should be positioned exactly over the centre of the steel joint, the dies in the press replaced by those for the aluminium sleeve, and the aluminium sleeve compressed beginning where the steel sleeve ends and working out towards the ends in turn away from the centre which is left uncompressed (see Fig. 284).

To prevent the conductor from bulging at the ends of the aluminium sleeve, servings of soft wire should be applied 15 to 20 mm away from its ends.

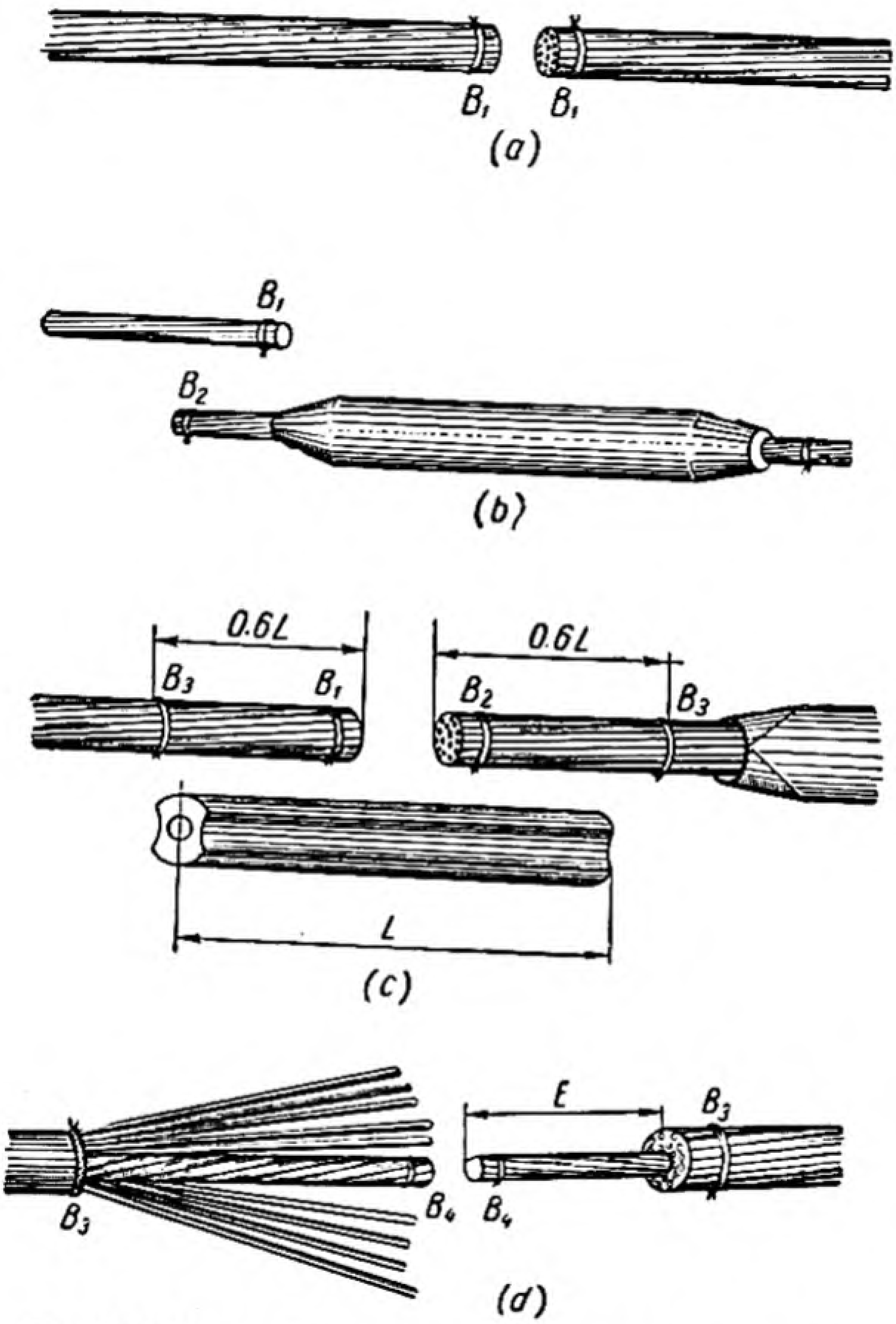


Fig. 284. Steps of jointing conductors by compression

The aluminium joint is compressed in the same manner as the steel joint.

The earth-wire is also jointed as the above conductors are.

To prevent corrosion, red-lead paint is applied where the conductors and earth-wire come out of the joints.

Dead-ending, tensioning and clamping of conductors. After the conductors have been run out along the line and jointed where necessary, they are made fast to the anchor support from which the tensioning operation is to be started. First, tension clamps are put on the conductor; with them it is secured to the insulator string. These tension clamps may be either of the bolted type or of the compression type. General views of a bolted-type tension clamp can be seen in Fig. 239 and in Fig. 245*a*. The conductors are secured in them in the same way as the buses are mounted in an outdoor substation (see Sec. 37).

The compression-type tension clamp is very similar to the compression joint used on steel-cored aluminium conductors.

After the clamps are in place, they are attached to their tension insulator strings and lifted together with the conductor on the anchor support with a rope passed over a block attached to the support cross-arm and taken to the pulling mechanism which may be a winch, tractor, or truck. The lifting rope should be made fast to the third insulator from the top of the string. A special insulator lifting clamp should be used for this purpose (see Fig. 279).

When the conductors have been clamped and dead-ended at the back anchor support (in the direction of pull), the conductor at the other end of the anchor span is attached to a comealong clamp, passed over a sagging block, and is hoisted together with it on the support cross-arm. The conductor end carrying the comealong clamp is made fast to the pulling mechanism.

The necessary sag is then adjusted with the aid of sighting battens set on the supports at each end of a span (Fig. 285).

It is good practice to give the conductor a certain amount of overtension at the pulling point in order to even up the sags in all the spans of the given anchor span.

For this reason sags are sighted in the span furthest from the pulling point and in the span nearest to it. The necessary sag is first set in the furthest span and then in the nearer span.

It should be noted that sag tables give a reduced sag in order to provide for its increase due to sleet and heavy wind loading, etc., so that the necessary clearances will not be decreased.

At the second anchor support the tensioned conductor is marked with binding wire applied where the tension string is to be secured at a given sag, the conductor is lowered to the ground, and another wire binding is applied at a distance equal to the length of the ten-

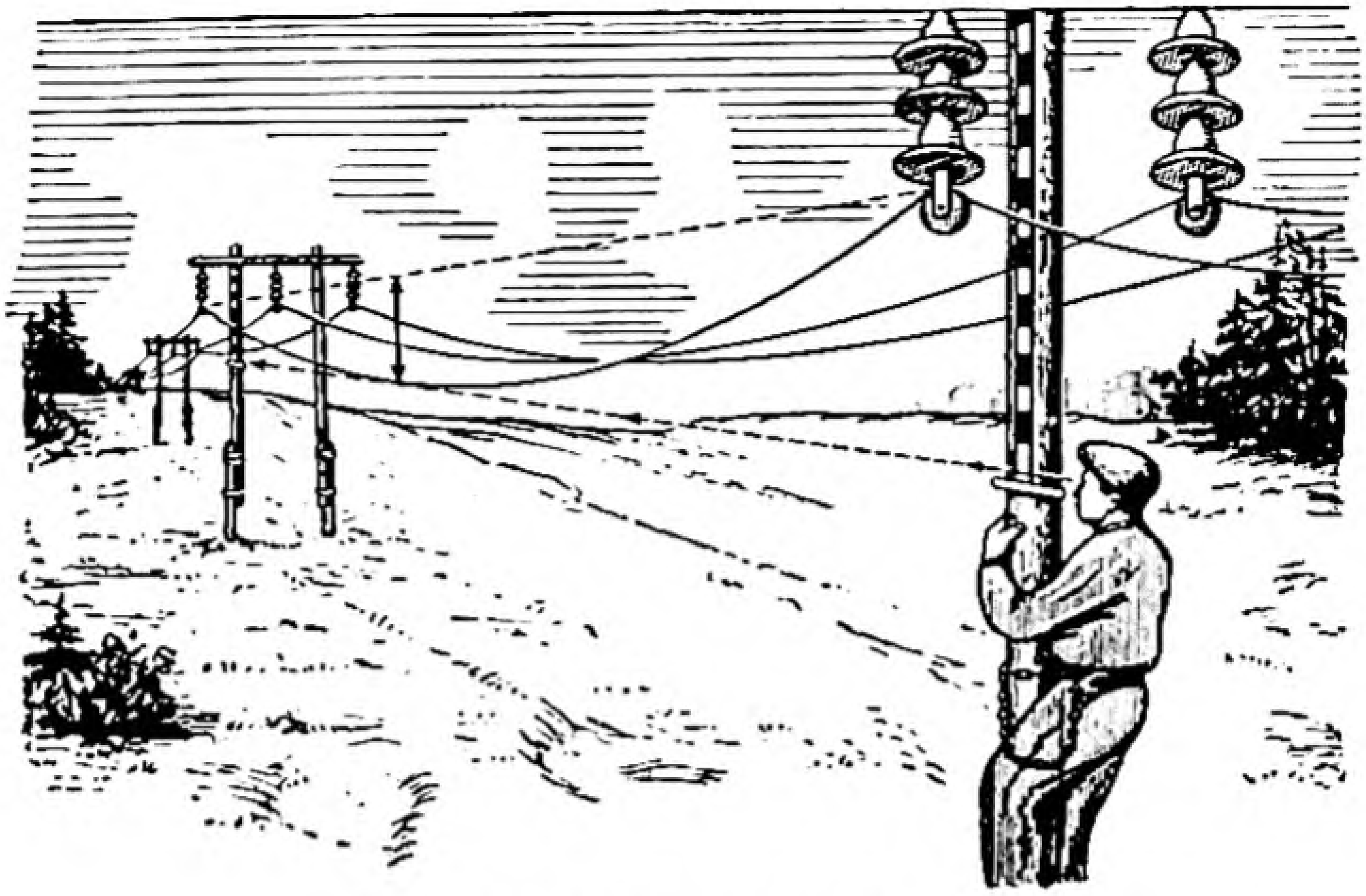


Fig. 285. Method of adjusting sag

sion string and clamp back from the first binding; the tension clamp is fitted on the conductor in the same way as at the first anchor support, and the tension string and clamp assembly and the conductor are hoisted to the support cross-arm where the tension string is made fast.

Frequently the tension clamp is secured to the second anchor support without lowering the conductor to ground. In such cases the clamps are installed from cradles.

After a conductor has been strung, the snatch blocks used for stringing are replaced at the intermediate supports by suspension clamps. This work is performed by two workmen (Fig. 286).

One of them climbs the support and secures a block and rope to the cross-arm and drops the end of the rope down. Using the rope and block, the other man raises a tackle, hanging ladder and the necessary number of suspension clamps.

The man on the cross-arm now secures the ladder and tackle to the cross-arm, descends the ladder level with the conductor and engages the conductor with the tackle hook. To protect the conductor from damage, it is first wrapped in a rag.

The man working below pulls up the conductor by means of the tackle to permit the man at the top to remove it from the snatch block and replace the latter with a suspension clamp. When the clamp is in place, the conductor is lowered and slipped into the clamp by

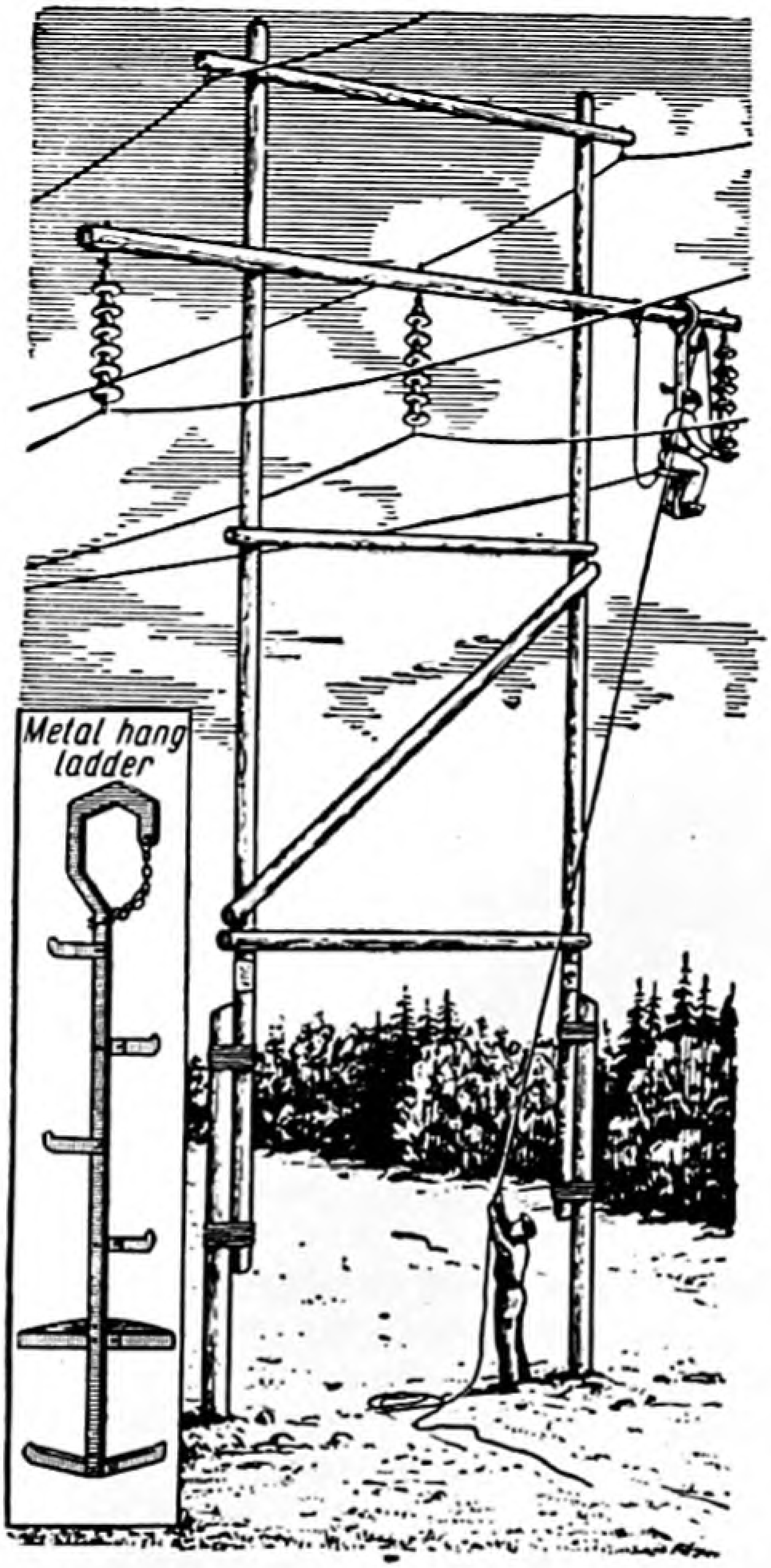


Fig. 286. Transfer of conductor from snatch block to intermediate suspension clamp

paying out the fall rope. Before the conductor is fixed in place in the clamp by the bolts, the suspension string should be aligned for true verticality.

Before aluminium or steel-cored aluminium conductors are clamped, they should be wrapped in aluminium tape about 10 mm wide and 1 to 1.5 mm thick.

55. Safety Rules for Installation of Conductors and Earth-wires

Before commencing the installation of conductors and earth-wires, the wire-stringing equipment should be examined for possible defects.

Those working on supports should wear safety belts reliably secured to the support.

Electricians should never be allowed to work on angle supports inside of the turn-angles of change in the direction of the line, as they may be struck by conductor going loose.

Nobody should be allowed to stand under an insulator string or conductor when it is being lifted on a support, or under the conductors and supports when conductors are being run out, strung, or sagged.

Tools or line fittings should never be allowed to fall from a support or a man to descend down a rope from the block used for lifting insulator strings and conductors.

As a thunderstorm comes up, all work on a line must be immediately discontinued.

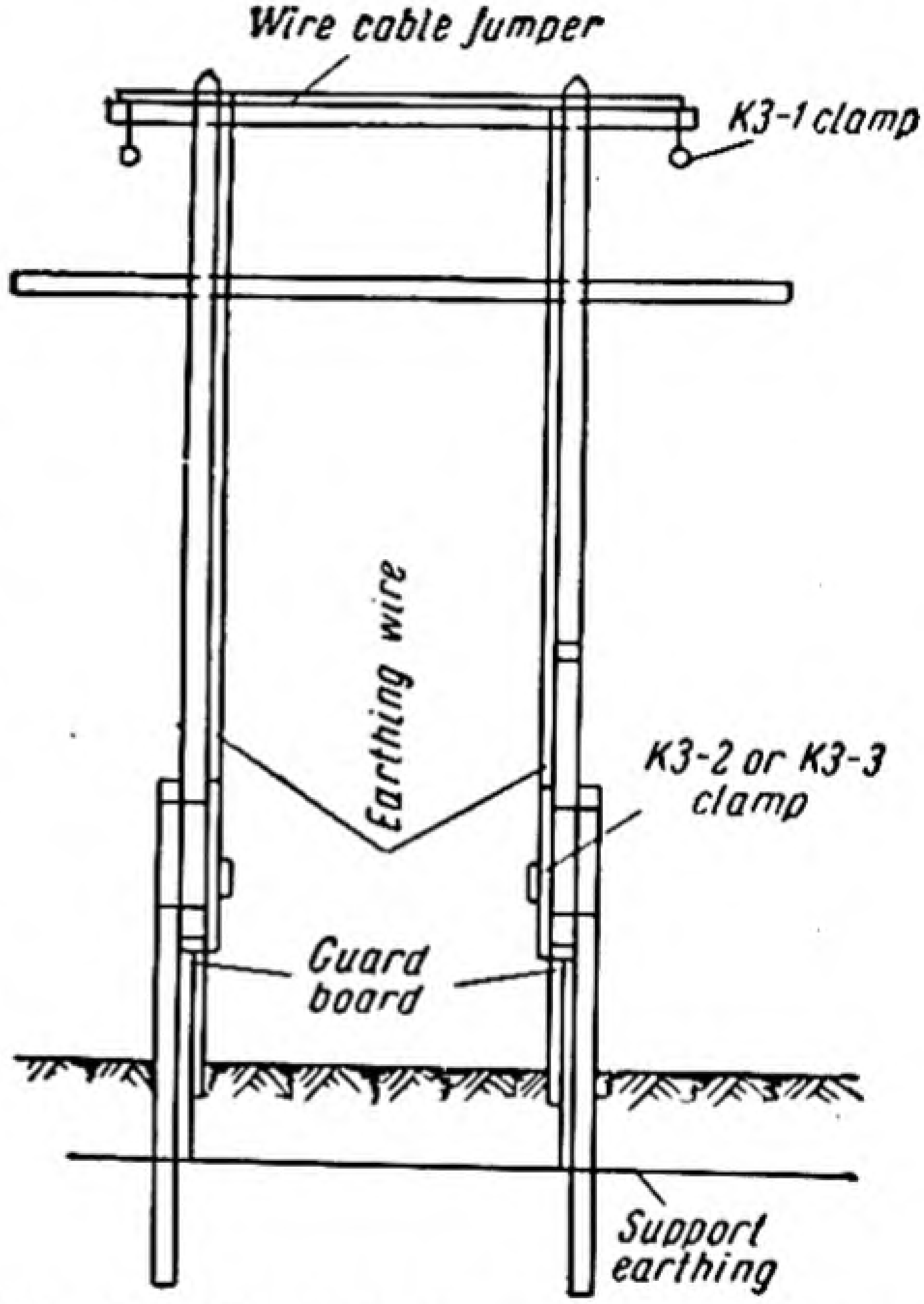


Fig. 287. Example of earthing conductors installed on a wood-pole support

56. Lightning Protection of Overhead Lines

The two methods of protecting overhead lines against lightning strokes are: (1) overhead earth-wires and (2) expulsion protector tubes.

The overhead earth-wire is strung along the line above the conductors and connected to the two earthing electrodes driven into the soil at each support. The earthing electrodes are steel pipes 1½ inches to 2 inches in diameter or $40 \times 40 \times 4$ mm iron angles not less than 3.5 metres long.

All buried earthing connections should be welded. The earthing conductors run down from the earth-wire are connected to the latter by means of bolted-type clamps. At the bottom of a support pole they should be protected against mechanical injury to a height of 2 metres above ground level.

An example of earthing conductors installed on a wood-pole support is shown in Fig. 287.

Expulsion protector tubes consist of a bakelised fibre tube containing two built-in electrodes between which an internal gap is provided.

An outer electrode, or arcing horn, made from steel wire 5 or 6 mm in dia is attached to the bolt at the upper end of the expulsion tube

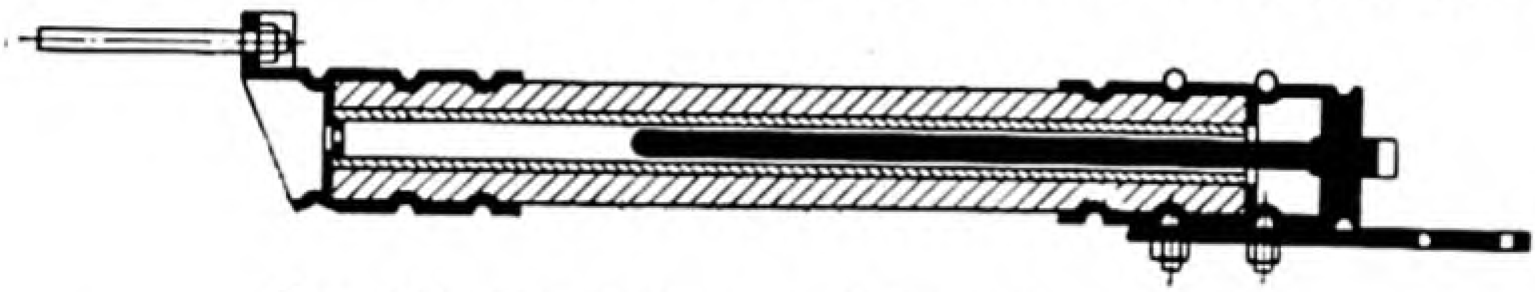


Fig. 288. Power line expulsion protector tube

(Fig. 288) to provide an external spark gap between it and a line conductor.

Expulsion tubes are connected to supports by mounting brackets which should be reliably earthed. The internal gap can be adjusted by turning the tube about the bolt which secures the tube to the bracket. The external gap is adjusted to templates made from wire 3 or 4 mm in diameter.

Expulsion tubes should be mounted so that their base is not less than 2.5 metres above ground level. When it is impossible to observe this distance, special fencing must be provided.

PART TWO

OPERATION AND MAINTENANCE OF STATION, SUBSTATION AND LINE EQUIPMENT

CHAPTER 10

ORGANISATION OF OPERATION AND MAINTENANCE

57. Scope and Principles

By the operation and maintenance of station, substation and line equipment is meant all activity required to keep the entire system of power generation, transmission and distribution in running order.

The objectives of operation and maintenance, which is an involved and responsible process, are:

(1) to provide planned total output and supply at peak loads;

(2) to provide continuity of power supply at a constant frequency and rated voltage;

(3) to keep unit cost of power at a minimum.

The Soviet managerial structure of operation and maintenance is shown in Fig. 289 for a thermal power station.

Referring to the diagram, the management of a power station is organised along the same lines as that of any industrial undertaking in the Soviet Union, i. e., it is headed by the director to whom the chief engineer and other staff members report. However, there is some duality in this system of management. For one thing, the shift (control) engineer (Fig. 290) reports to both the director and the regional power authority, in particular the system dispatchers.

This duality, seemingly contradictory to the principle of direct responsibility, is due to the following circumstances.

As will be recalled, the individual power generating stations are not operated in isolation but are interconnected by power grids into integrated systems and therefore operate in parallel. This necessitates their co-ordination, which is catered for by the chief dispatcher who, while on duty, is in charge of the entire system, and has the control engineer at each power station under his direct orders.

At a power station all staff is divided into shift operators and maintenance men.

The shift operators do the necessary switching operations, keep watch on the operation of the electrical equipment, remedy any abnormal conditions, partake in eliminating any emergency, take out equipment for repair and put it back in service after repair.

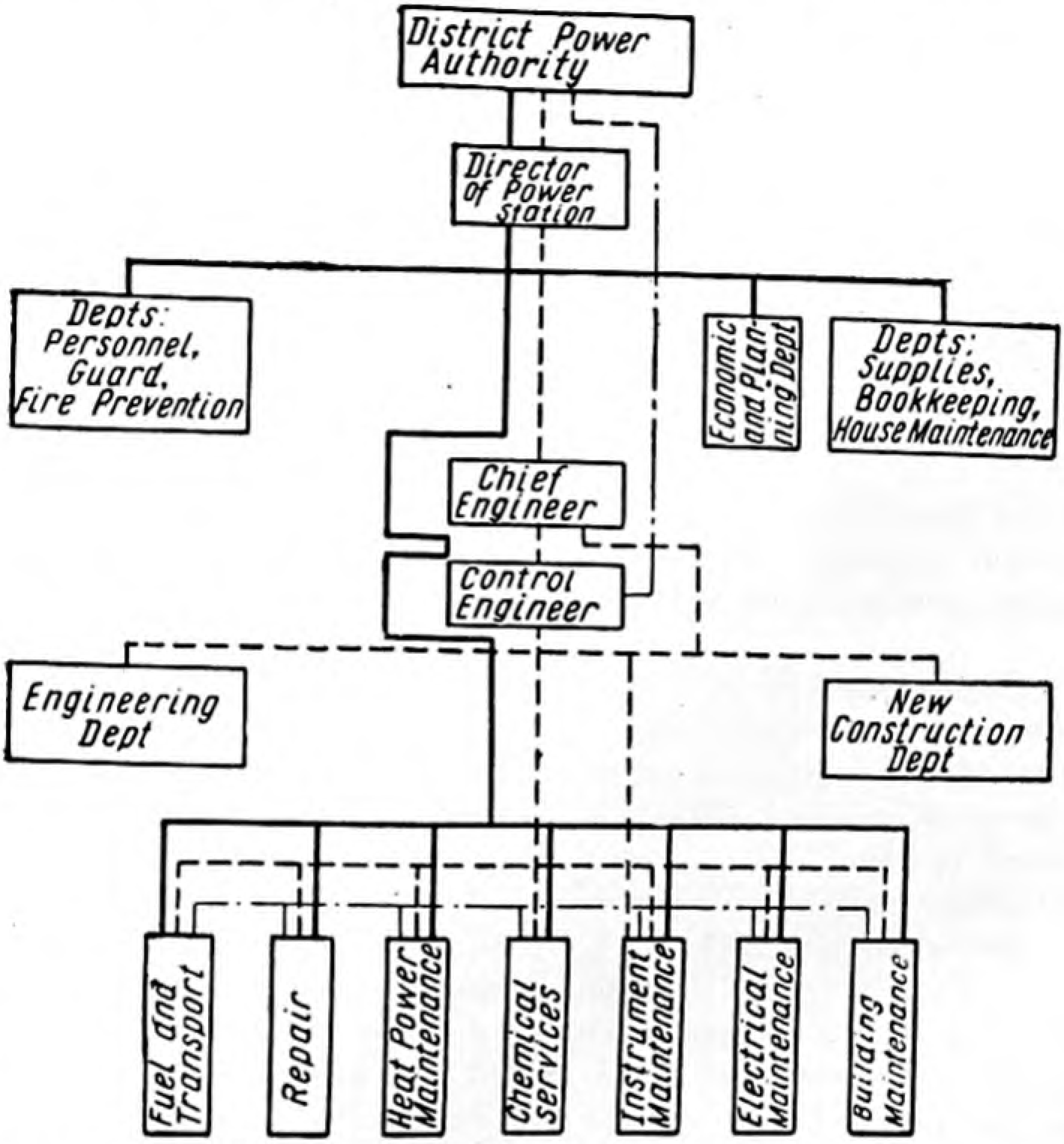


Fig. 289. Structure of thermal electric power station management

As far as switching operations are concerned, the operators report only to the chief operator (control engineer).

At the same time each operator reports to the superior within a given department. Thus, the control engineer at a station ought not to switch on the equipment which the chief engineer of the station considers faulty. Any machine or unit after it has been repaired may only be put into service by permission of the head of the respective department. The operators are obliged to follow the regulations approved by the chief engineer of the station.

The maintenance men service and repair the equipment and are, for this, divided into crews headed by foremen. Each foreman and his crew are assigned to a section or group of equipment, for example, the switchgear, the generators, the station services, etc.

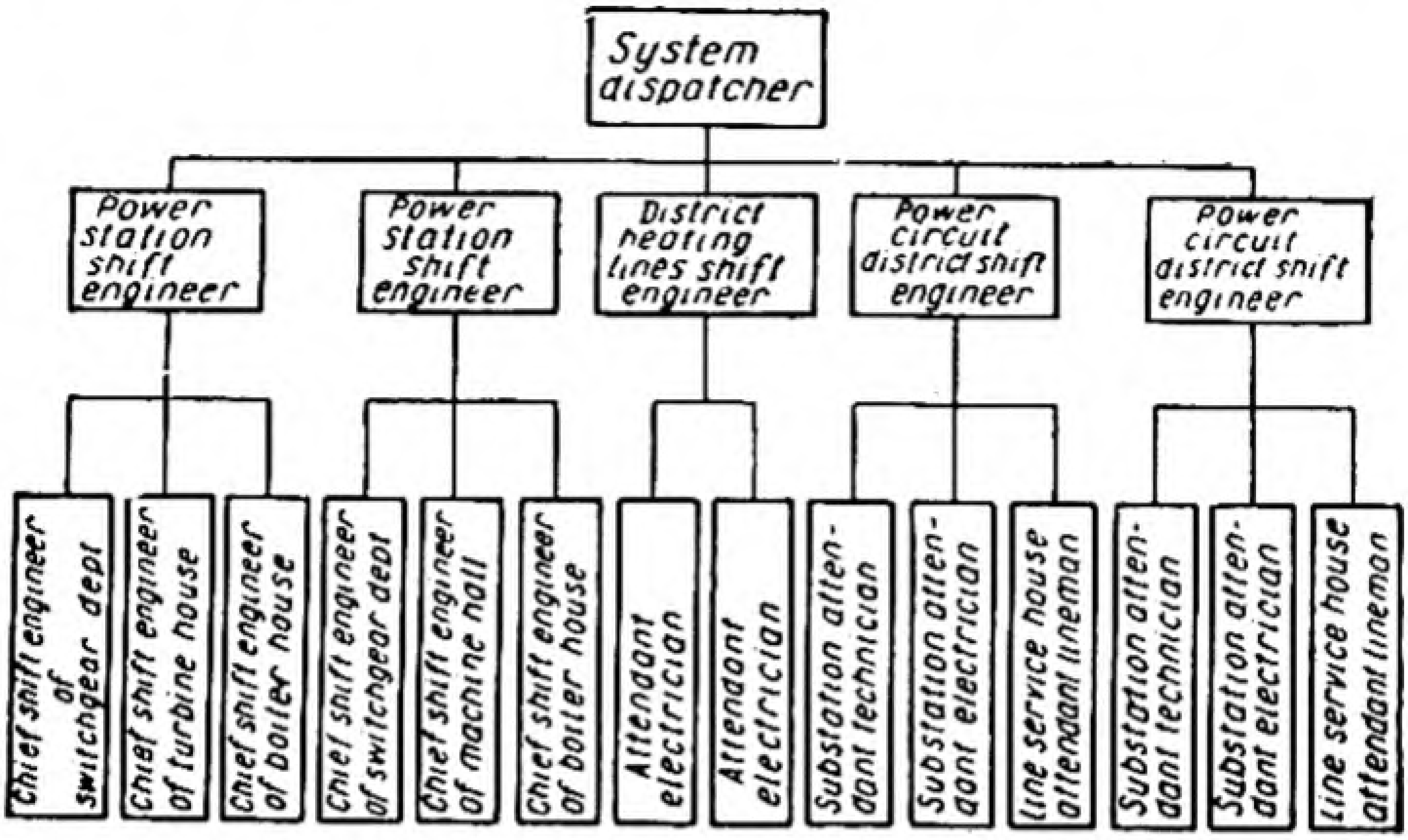


Fig. 290. Structure of subordination of operative personnel

58. The Electrical Maintenance Department of an Electric Power Station and Its Functions

The electrical equipment of all the departments of a station is maintained by the station's electrical maintenance department, the organisational structure of which is shown in Fig. 291.

The electrical maintenance department is in direct charge of some of the equipment such as the switchgear equipment, transformers, and control board, and only services other equipment, including the electric motors in the various departments.

The electrical maintenance department is also responsible for the electrical part of the turbogenerators, while their mechanical part is placed under the supervision of turbine house personnel.

The work of the electrical maintenance department operative personnel is supervised by the shift chief (see the diagram in Fig. 291). Attached to him are the control board attendant, floating electrician and his helper.

The change of the shift is an important moment in the work of the operative personnel and the procedure is as follows.

The new shift chief, before taking on duty, is obliged to inspect the equipment, to see which equipment and circuits are switched in or out, and to obtain information about the operating conditions. Special emphasis is placed on the major and more vital units, such as the generators, power transformers and high-capacity motors.

In taking over, the new shift chief should learn which units require special care, what equipment is in standby, and what equipment has been taken out for repair.

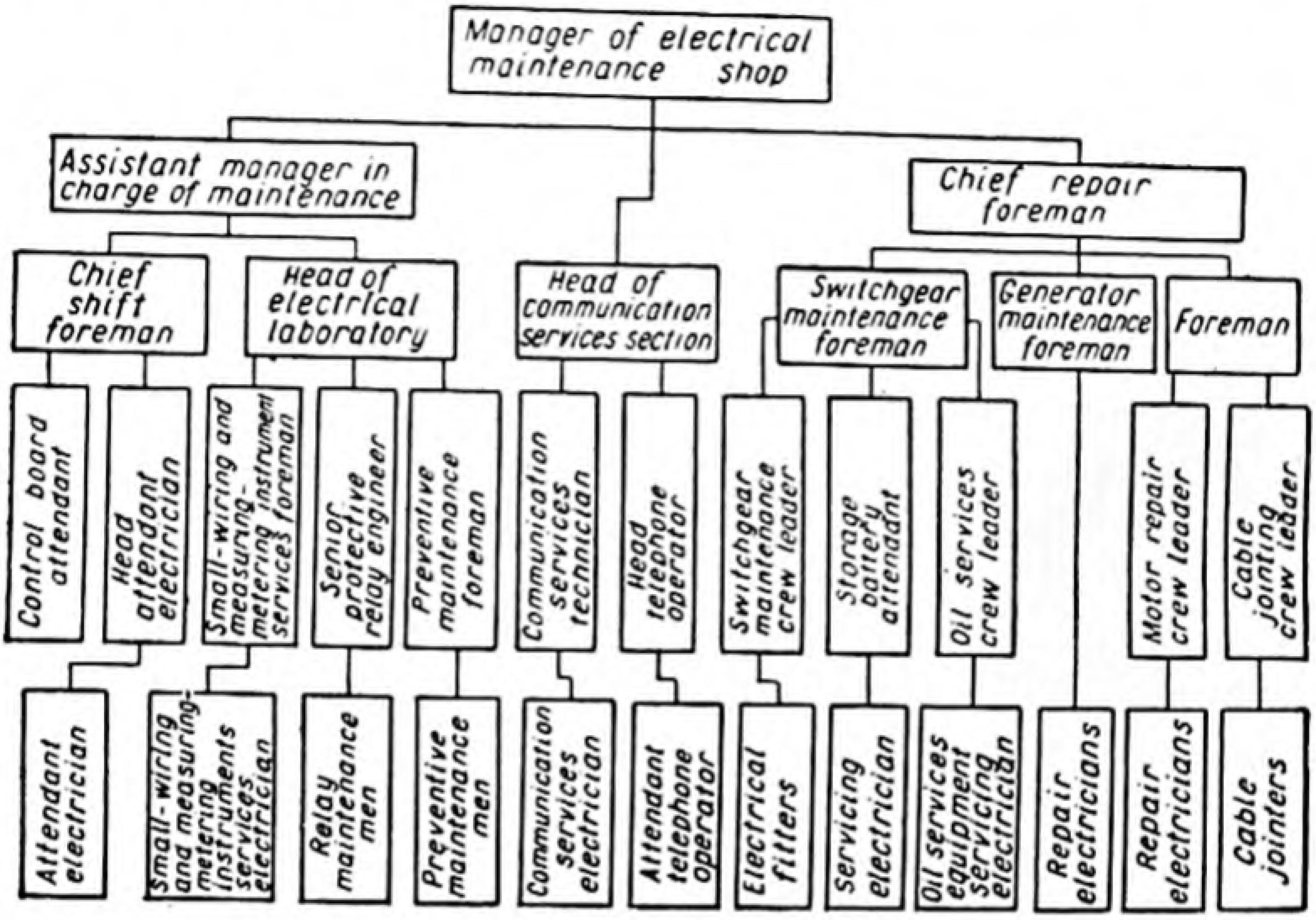


Fig. 291. **Organisational structure of the electrical maintenance department of a power station**

Also he should read the notes in the log-book to learn what abnormalities occurred during the previous shift and what orders were given by the operator in charge.

The new shift chief takes over the keys, tools, instructions, and the log-book, in which the man leaving duty signs off and the man taking on duty signs in.

The relieving attendant should inform his chief operator of any abnormalities he has detected.

The relieved attendant should report to his engineering chief of the condition of the equipment when he hands over duty.

The shift chief is responsible for operation of all equipment in his charge during his period of duty. He directs the elimination of any abnormal conditions and breakdowns in the equipment, and makes periodic rounds of the equipment.

The control board attendant keeps constant watch on operation of the generators and adjusts their loads to the orders received from the chief operator. He also watches the power transformers and lines, and the storage batteries and their charging units.

The floating electrician makes rounds of the various departments of the station, remedies any troubles in operation of the electric motors, lighting circuits, etc.

59. Training of Operating and Maintenance Personnel

To be efficient in discharging their duties, both the operators and maintenance men should have a perfect knowledge of the equipment which they operate or service and of the conditions under which it must be operated, and possess the necessary practical skills.

Technical knowledge is acquired at vocational training schools where workmen are trained in the various electrical engineering trades.

A vital stage in this training is on-the-job training which is provided for by the respective curricula and in which the training course usually terminates.

A trainee operator, for example, is assigned to an experienced attendant. The trainee goes through his tours of duty as established by the regulations at the station, but has no right to carry out any routine switching unless told to do so. The experienced attendant bears full responsibility for all work done by the trainee.

The term of on-the-job training varies with the training course and in accordance with the job the trainee is being prepared for.

Before he is given a job, the applicant should qualify for it before a qualification board set up directly at the power station.

After the applicant has passed the qualification tests, he receives a certificate entitling him to work on electrical equipment, and is also assigned a safety group rating (see below). Each newcomer assigned to a job at an electrical power establishment has first to work as a probationer for a certain period of time.

Everyday advancement in qualification is attained through systematic technical education of personnel. This activity covers acting codes and regulations on operation, maintenance and safety, and local and general operating instructions.

A great deal of attention is devoted to familiarisation with the equipment already in service and planned for addition.

Briefings at which all departures from normal operation during the previous shift are discussed go a long way towards raising the

qualification of personnel. Special attention is given to cases of damage to equipment and emergency, and to an analysis of their causes.

These briefings are held either before or after a shift depending upon the circumstances and the decision of the chief engineer.

To train personnel to cope with emergencies, so-called mock-emergency exercises are periodically conducted.

The subject of a mock-emergency exercise is worked out by the engineering staff in advance. Such exercises may be conducted directly on the operating equipment, or on equipment in repair or in reserve.

As is advised in relevant instructions, linemen should be trained on lengths of line built for the purpose of training in the change of insulators, live-line work, etc.

Operators learn much from briefings held at their work places by the engineering and managerial staff on the shortcomings noticed during rounds of their equipment. Each operator in a shift at an electric power station, substation or dispatcher's office should be given at least one on-the-spot briefing every month.

CHAPTER 11

SWITCHING OPERATIONS

60. General

Switching operations are performed whenever it is necessary to make a change in the connections, take a unit of equipment out for repair or when emergencies arise.

Switching operations are the most responsible of the duties of operative personnel in generating stations and substations. They are classed as simple and multiple.

For a correct switching a definite sequence is essential. As experience has shown, most of the gross errors in the performance of operative switchings are due to failure of attending personnel to follow the proper sequence. This is particularly true of simple switchings, well known to the attendant and successfully performed by him very many times. These are the opening of an isolator switch under load, application of voltage to a temporary safety-earthing set left unremoved from a place where work has been completed, opening of a wrong circuit breaker.

Basic switching rules. Switchings may only be entrusted to authorised and competent personnel.

All switchings in substations with voltages over 1,000 volts should be performed by two men, one man doing the actual switching, the other man standing by to see that he performs the operation correctly. The man supervising the performance of the man doing the switching shall be higher in rank and have a safety rating of not below Group IV. The rating of the man performing the switching operation shall not be below Group III. Circuit breakers in metal-clad switchgear and in unit transformer substations, as well as in plant for voltages up to 1,000 volts may be operated by one operator having a safety rating of not below Group IV.

A single attendant may apply a temporary safety-earthing set only when there are provided mechanically operated earthing blade

contacts. Otherwise, a temporary safety-earthing set may only be applied by two attendants.

All switching operations in the switchgear of electric power stations and substations are performed on orders received from the chief operator of the system.

Multiple switching operations in substations with voltages above 1,000 volts are performed to written orders filled out on standard switching forms. A standard form is given below.

Switching form

Name of establishment________________________________

SWITCHING FORM No. 10

Name of installation________________________________
(power station, substation, switchgear, power line)

Date:______________ Work began______________ hrs

Work ended______________ hrs

Task: Disconnect and earth 110-kv power line No. 2

Sequence:

1. Open No. 2 line circuit breaker.
2. Prove that No. 2 line circuit breaker is fully open.
3. Check to see that No. 2 line isolator switch is de-energised.
4. Open No. 2 line isolator switch.
5. Close earthing blade contacts of line No. 2.
6. Open No. 2 line bus coupler for isolation from 2nd bus.

Signed by______________ Signed by______________
(Person who performs the operations) (Person who supervises the operations)

Notes: 1. This form must be filled in before any switching is to be performed.

2. All operations should be entered in precisely the same sequence as will be actually followed.

No switching forms are required for any simple switchings.

Any switchings during the hours of peak load or at the end of a shift may be permitted only in cases of emergency.

61. Operation of Isolators

As a rule, isolators may only be operated after the circuit breaker has interrupted the load current. The reason is that isolators have no arc-control devices (Fig. 292).

To minimise the consequences of wrong operation of isolators the following procedure has been established for an operator to observe should an arc strike.

For the worm and worm-gear type of operating mechanism in which the switch blade moves slowly, a closing stroke must be

brought to completion irrespective of the arc. Should an arc strike on an opening stroke the blade should be immediately moved back. As a result, in both cases the arc is shunted and extinguished.

For the lever type of operating mechanism by which the travel of the blade cannot be practically reversed, any operation once begun, whether closing or opening, must be completed under all circumstances in a resolute and quick manner.

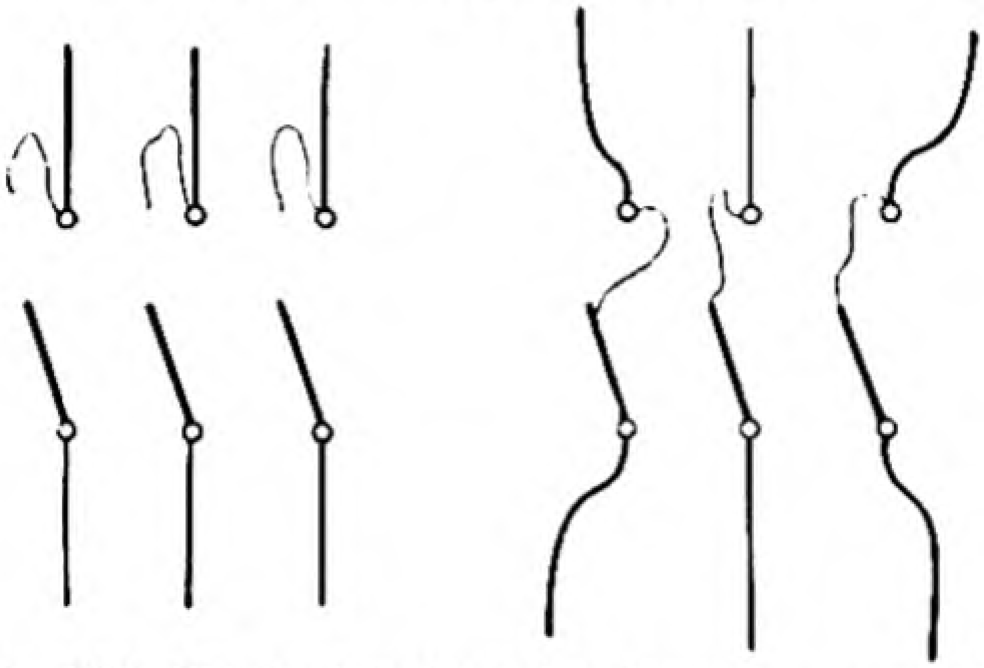


Fig. 292. Effect of isolator bus layout on probability of short circuit due to false isolator operation

Isolators may be used to break and make the following currents:

(a) instrument transformers currents;

(b) main-bus charging current;

(c) power-transformer neutral current;

(d) earth-fault currents up to 5 a in 20- to 35-kv power lines and up to 10 a in lines of 10-kv or lower voltage;

(e) charging currents of overhead and underground cable lines of the following voltage ratings and lengths:

(I) overhead lines up to 20 kv, irrespective of length;

(II) 35-kv overhead lines up to 30 km long;

(III) 110-kv overhead lines up to 20 km long;

(IV) underground cable lines with voltages up to 10 kv and up to 10 km long.

Isolators may also be used for transfers from one bus to another.

In pole-mounted substations which are not equipped with circuit breakers, three-pole mechanically-operated isolator switches may break line load currents up to 15 amperes at line voltages up to 10 kv.

Three-pole isolators, either mechanically or electrically operated, may also be used to break and make the no-load currents of three-phase power transformers of the following ratings:

(I) up to 750 kva at up to 10 kv inclusive,

(II) up to 5,600 kva at up to 20 kv inclusive,

(III) up to 20,000 kva at up to 35 kv inclusive,

(IV) up to 31,500 kva at up to 110 kv inclusive.

On power transformers of 35-kv and higher rating the no-load currents may be switched on and off by horizontally mounted PJIH isolators installed with an increased interphase distance of 2,000 mm for 110 kv, and not less than 1,200 mm for 35 kv.

Under no circumstances shall isolators be used:

(1) for on-load change over from the main to the transfer bus;

(2) for closing or opening a bus system when the circuit breaker is closed, except for the cases stated above.

When single-pole isolators are used, the wrong opening of the blade will not produce a heavy arc, because the interrupted phase will have its voltage maintained by the other two phases. In such cases it is necessary to reclose the opened phase or immediately open the circuit breaker, but in no case should a second phase be opened, as then the isolator will break the load current.

62. Examples of Simple Switchings

The simplest switching operations include the connection or disconnection of underground cable and overhead lines and disconnection of motors.

The following procedure has been adopted for opening bus and line isolators: the circuit breaker is opened first, then the line isolators and finally the bus isolators are opened. With this sequence, should a line isolator be used wrongly to interrupt the load current, the protective relays of this bus will trip the circuit breaker open. Otherwise the substation busbars would be faulted.

When a line is to be energised, the bus isolators are closed first, then the line isolators and, lastly, the circuit breaker. A wrong sequence with a bus isolator will cause a much more severe breakdown than with a line isolator. Typical simple routine switchings used to take out a unit of equipment for repair or put it into operation are discussed below.

Switch-out of a 10-kv cable line circuit breaker for repair. A call from a consumer informs that line No. 5 has been disconnected by the circuit breaker and line isolators (Fig. 293) at their end.

The procedure for the operators:

(1) check line No. 5 for load current with an ammeter;

(2) open the circuit breaker of line No. 5;

(3) hang a "Do Not Operate—Men at Work!" notice on the operating-mechanism handle of the No. 5 line circuit breaker;

(4) depending upon its type, check the position of the breaker by the tell-tale or the contacts to make sure that the No. 5 line circuit breaker is open, and then de-energise the operating mechanism;

(5) check to see that the line isolators on line No. 5 are de-energised and open them;

(6) disconnect the No. 5 line bus isolators from the operating bus and check to see that they are fully open;

(7) padlock the operating mechanisms of the opened No. 5 line isolators;

(8) check to see that there is no voltage across the terminals of the No. 5 line circuit breaker and attach two temporary safety-earthing sets: one on the bus side, the other on the line side.

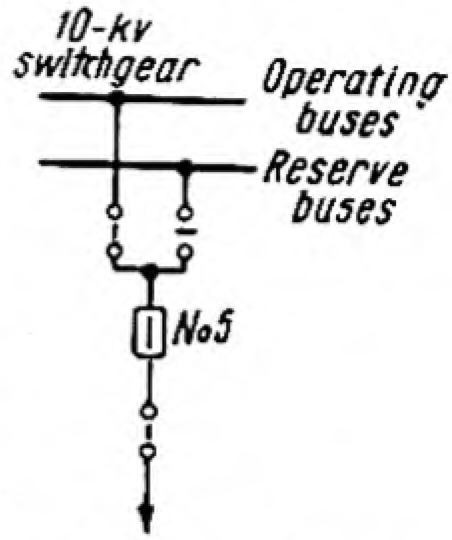


Fig. 293. Connections when 10-kv cable line circuit breaker is to be switched out for repair

Take-out for repair of one of two 10-kv cable lines using a common circuit breaker (the cell has fireproof barriers between the line isolators). To begin with, 10-kv cable No. 3 of line No. 3+8 (Fig. 294) should be disconnected at the consumer's end. If its length is more than 10 km, its charging current must never be interrupted with the isolators.

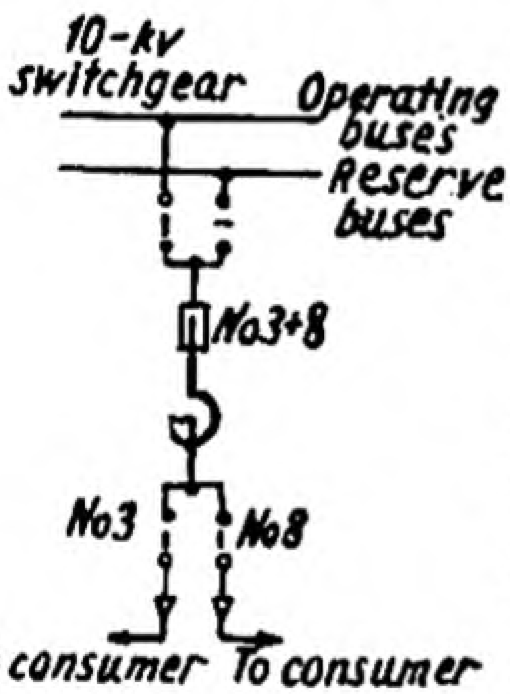


Fig. 294. Connections when one of two 10-kv cable lines fed in parallel through one circuit breaker is to be switched out for repair

The procedure for the operators (for cables up to 10 km long):

(1) check the cable with an ammeter for load current;

(2) open No. 3 cable line isolators;

(3) padlock the line-isolator operating mechanism;

(4) hang a "Do Not Operate—Men at Work!" notice on the line-isolator operating mechanism;

(5) inform the consumer that cable No. 3 has been de-energised, after which the consumer may, with due precaution, apply a temporary safety-earthing set, hang up the required warning notices and carry out the necessary repair work.

Disconnection of a station auxiliary motor for repair. The station's engineer in charge has ordered that the electric motor of district-heating pipeline pump No. 3 be taken off the line for repair. This motor receives its supply from a 3-kv metal-clad station switchboard (Fig. 295).

The procedure for the operators:

(1) give an order to the heat-power service department to put standby pipeline pump No. 4 into operation and take over the load from pump No. 3;

(2) make sure that pump No. 4 and its motor operate normally;

(3) switch off the motor of pump No. 3 and hang a "Do Not Operate—Men at Work!" notice on the control handle;

(4) de-energise the operating mechanism of the circuit breaker of No. 3 pipeline pump motor;

(5) draw the circuit breaker of the No. 3 pipeline pump motor out of its compartment into the repair position;

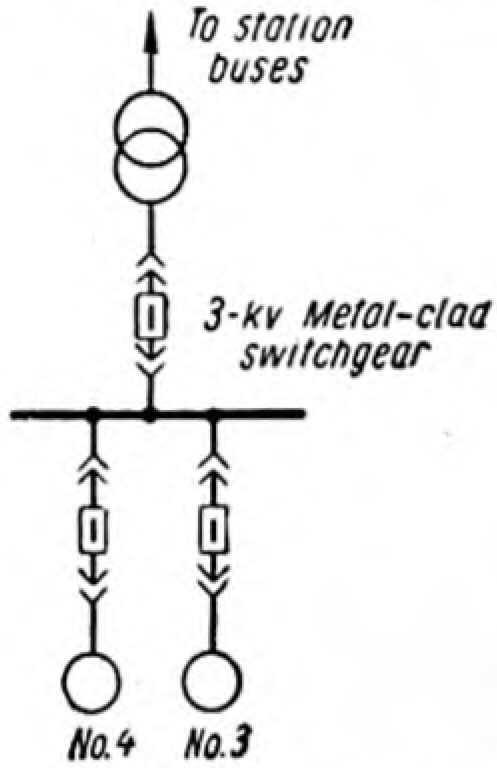


Fig. 295. Connections when a station-auxiliary motor is to be taken out for repair

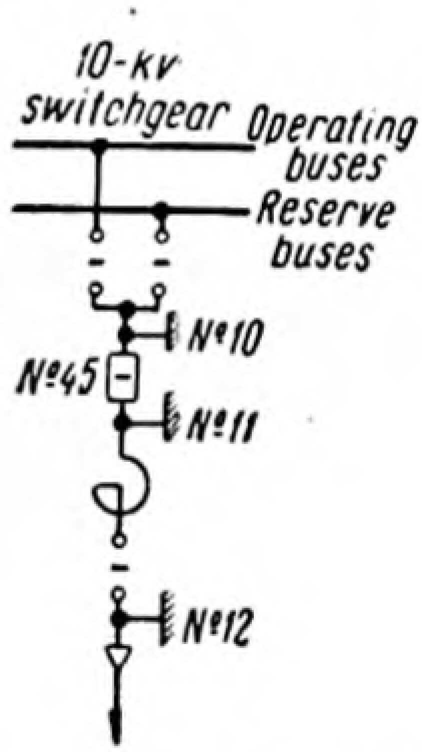


Fig. 296. Connections when a 10-kv line is to be switched back into operation after repair

(6) check for absence of voltage, disconnect the supply cable from the motor terminals and short it;

(7) take measures to prevent the motor from being turned by the pump (to be done by heat-power services department personnel).

Connection of 10-kv line after repair. An order has been received to switch in line No. 45 after repair (Fig. 296).

The procedure for the operators:

(1) remove No. 10 and No. 11 temporary safety-earthing sets devices from the circuit breaker and No. 12 safety-earthing set from the line isolators of line No. 45; also remove all warning notices and temporary guards;

(2) check the tell-tale or the contacts to make sure that the No. 45 line circuit breaker is open;

(3) unlock the line No. 45 line-isolator operating mechanisms;
(4) close the bus isolators on the main bus side;
(5) close the line isolators;
(6) energise the No. 45 line circuit breaker operating mechanism;
(7) close the circuit breaker;
(8) inform the consumer that the voltage has been applied to line No. 45.

63. Examples of Multiple Switchings

The multiple switchings cover change-overs from one bus to another with and without the aid of bus couplers, the switching in and out of three-winding transformers, partial change-over from one set of buses to another, etc. Below are two cases of multiple switchings.

Disconnections for repairs associated with a transformer operated in parallel. It is necessary to open the connections of a transformer T_1 (Fig. 297) to carry out repairs on the circuit breakers on both the 10-kv and 35-kv sides.

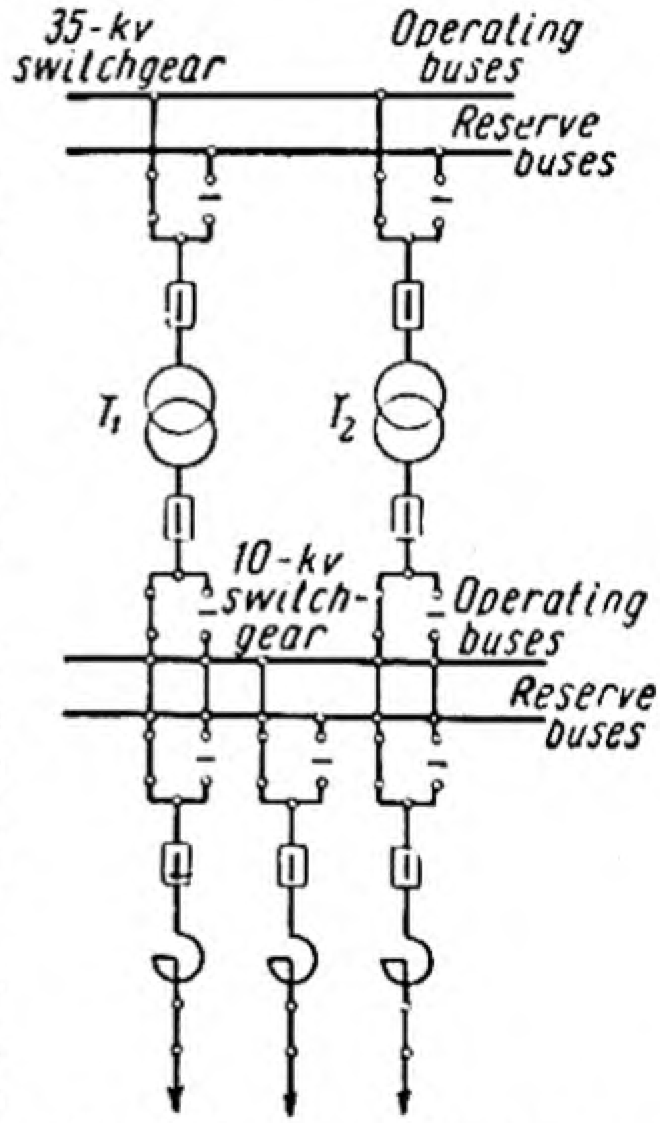


Fig. 297. Connections when a transformer operating in parallel with other units is to be switched out for repair

The procedure for the operators:

(1) find out what load the transformer T_2 will have to carry after the transformer T_1 has been taken off the line;

(2) trip the circuit breaker on the 10-kv side of the transformer T_1, make sure that the transformer T_2 has taken over the load, and hang a "Do Not Operate—Men at Work!" notice on the breaker control key;

(3) trip the 35-kv-side circuit breaker of the transformer T_1 and hang a "Do Not Operate—Men at Work!" notice on the breaker control key;

(4) check the 10-kv-side circuit breaker of the transformer T_1 for complete opening and de-energise the circuit breaker operating mechanism;

(5) check the 35-kv-side circuit breaker of the transformer T_1 for complete opening and de-energise the circuit breaker operating mechanism;

(6) open the 10-kv isolators of the transformer T_1 in order to disconnect it from the main bus, check the isolators for full opening and then padlock their operating mechanisms;

(7) open the 35-kv bus isolators of the transformer T_1 in order to disconnect it from the main bus, check them for full opening and padlock their operating mechanisms;

(8) check to see that the circuit breaker of the transformer T_1 in the 10-kv substation is dead and attach a temporary safety-earthing set on the bus side;

(9) check to see that the circuit breaker of the transformer T_1 in the 35-kv substation is dead and attach a temporary safety-earthing set on the bus side;

(10) put up the necessary temporary guards, hang up the notices required by the safety rules, and then allow the repair crews to begin their work.

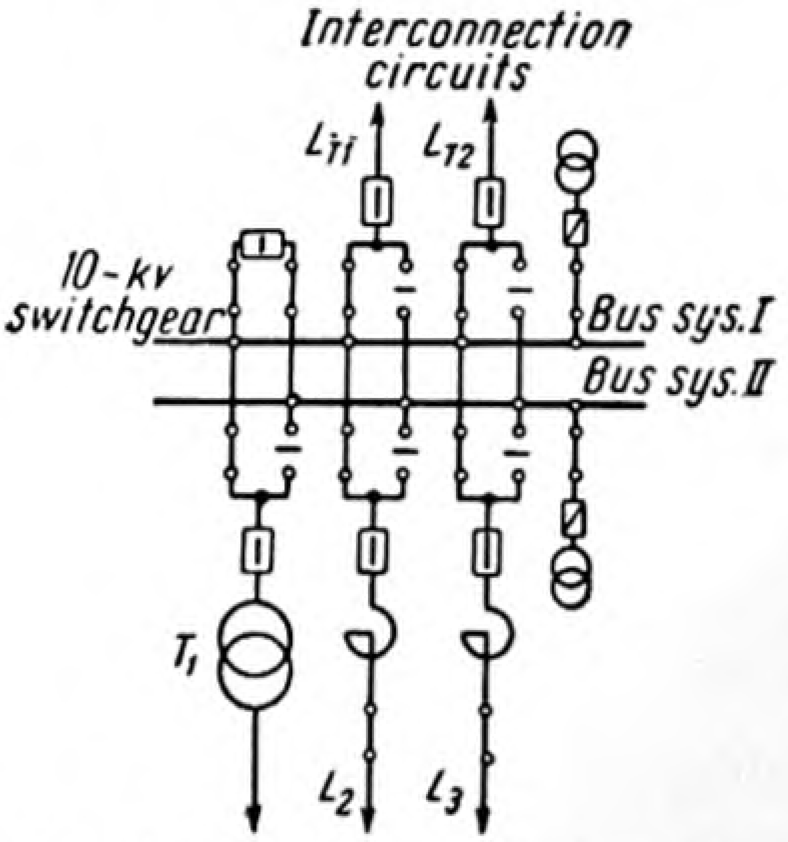


Fig. 298. Connections when a system of buses is to be taken out for repair

Disconnection of buses for repair. Bus *I* in a 10-kv substation has to be outed for repair (Fig. 298). The controls of the various bus isolators are located in different control aisles.

The procedure for the operators:

(1) examine bus *II* externally;

(2) adjust the protective relays of the bus coupler circuit breaker for the lowest overcurrent and time-delay settings;

(3) close the bus coupler circuit breaker;

(4) check to see that bus *II* is hot;

(5) de-energise the operating mechanism of the bus coupler circuit breaker;

(6) close bus isolators L_{T_1}, L_{T_2}, T_1, L_2 and L_3 of bus *II* and check them for full closing;

(7) open bus isolators L_{T_1}, L_{T_2}, T_1, L_2 and L_3 of bus *I* and check them for full opening;

(8) transfer the instruments, relays and automatic controls from the voltage transformer of bus *I* to that of bus *II*;

(9) using an ammeter, check to see that the bus coupler circuit breaker carries no load current;

(10) energise the operating mechanism and trip the bus coupler circuit breaker;

(11) de-energise the bus coupler circuit breaker operating mechanism and check its position at the breaker;

(12) open the bus coupler circuit breaker isolators of bus *I* and check them for full opening;

(13) open the bus isolators of bus *I* voltage transformers;

(14) padlock all operating mechanisms of the opened isolators of bus *I*;

(15) check to see that bus *I* is dead and attach temporary safety-earthing sets where the repair work is to be conducted;

(16) hang up the necessary warning notices, put up temporary guards and admit the repair crews.

CHAPTER 12
SWITCHGEAR MAINTENANCE

Switchgear maintenance consists basically of:
(1) inspections;
(2) preventive maintenance;
(3) repairs.

64. Switchgear Inspection

Periodic inspections of switchgear when it is in operation provide a check on its condition, reveal faults and defects which may develop during operation (failures in insulation, overheated connections, etc.) and make it possible to take timely measures to remedy them.

Attended substations should be inspected externally once a day. In addition, night inspections with lights off should be conducted at least once a week to reveal points of voltage or corona discharge and hot spots.

Unattended installations should be inspected at least once a month.

Each time a short circuit has been cleared, or the insulation is soiled heavily, or the weather is bad (wet snow, sleet storms, etc.), outdoor substations require more frequent inspection.

All troubles and defects discovered during an inspection should be entered in an inspection log-book and remedied as soon as possible.

On a regular round of inspection the person in charge should:

(I) examine the insulators, busbar contacts and current-carrying parts of apparatus for overall condition;

(II) inspect the knife switches and air circuit breakers for overall condition, the instruments for correct readings, the meters for missing seals and the rotation of the discs;

(III) examine the switchgear premises, the doors, windows and locks; make sure that the roofing does not leak, the heating system and ventilating facilities are in order;

(IV) test the alarm circuits for continuity and proper operation and safety aids for fit condition;
(V) check the apparatus for oil level and absence of oil leakage;
(VI) check the lighting circuits and earthing system;
(VII) examine the stand-by equipment.

65. Preventive Maintenance

Preventive maintenance of electrical equipment primarily amounts to testing the insulation and contact resistance of the various pieces of equipment.

Insulation resistance tests reveal defects and faults which cannot be discovered by external inspection. Though not upsetting normal operation of the equipment at the time of testing, these defects may later lead to a breakdown.

Insulation defects may be due to a variety of causes, such as overheating under overloads, excess moisture, mechanical injury, ageing, etc.

For preventive purpose it is normal practice to test the insulation of support insulators, bushings, isolator and fuse insulators, circuit breakers, instrument transformers, reactors, and lightning arresters.

Several methods exist for insulation testing: measurement of insulation resistance, impulse tests, measurement of dielectric losses in the insulation, and measurement of leakage current.

Measurement of the insulation resistance is the most generally used method for testing the insulation of switchgear equipment. This is done with 1,000- or 2,500-volt megohmmeters.

The M-110 megohmmeter (Fig. 299) is designed to measure high resistances such as encountered in the insulation of electric circuits, machine windings and various electrical installations.

It incorporates a 500- and 1,000-volt d-c hand-driven generator (*G*), a double-moving-coil indicating instrument and fixed series resistors electrically connected with each other. When the operating handle is cranked, the current developed by the generator flows through the coils (making up the moving system) of the indicating instrument, and also through the series resistors. The magnetic fields set up around the moving coils by the currents flowing through them interact with the field of the permanent magnet (poles *N* and *S*) in the instrument.

The deflection of the moving system depends on the ratio of the currents in the two coils. The unknown resistance under test is connected in series with one of the coils called the deflecting coil. With the generator furnishing a constant voltage, the current flow-

ing through the deflecting coil is determined solely by the value of the resistance under test; the current through the second (control) coil is independent of it.

The reading error of the above megohmmeter due to variations in generator speed is within 1% of full-scale value.

Insulation resistance may be tested with a megohmmeter only on de-energised circuits or equipment.

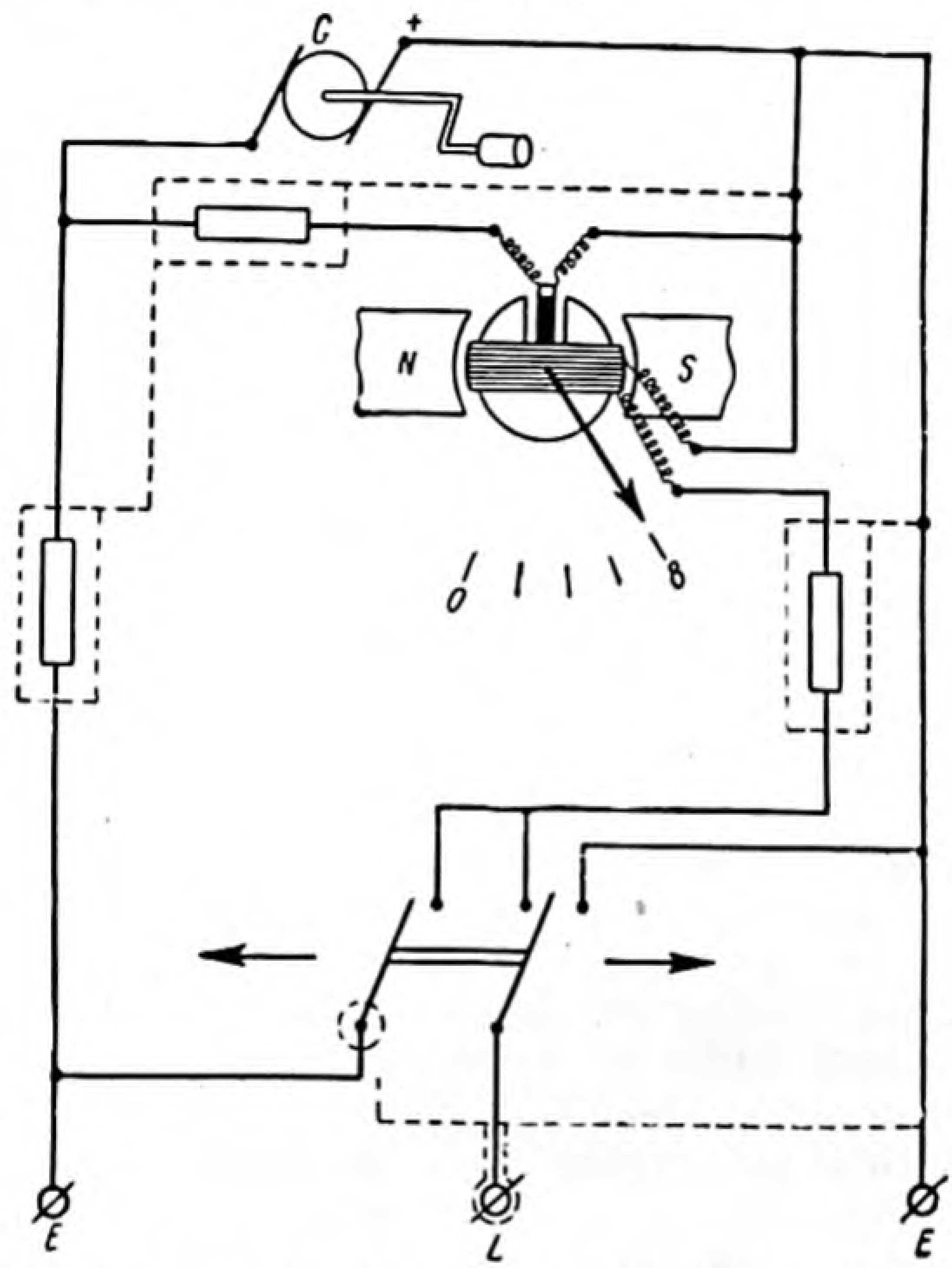


Fig. 299. Schematic diagram of the M-110 megohmmeter

For its ability to detect weak spots in insulation a megohmmeter depends on the fact that any deterioration in the insulation is accompanied by a sharp drop in the insulation resistance of one phase relative to another or to earth. In the absence of any evidence of insulation breakdown, megohmmeter measurements mainly indicate the degree to which moisture has been absorbed by the insulation or deposits have accumulated on it.

Moisture absorption is usually evaluated from the ratio of two values of insulation resistance measured with a megohmmeter, after 60 seconds and 15 seconds, respectively. This ratio is called

the coefficient of moisture absorption and is calculated by the equation $K = \frac{R_{60}}{R_{15}}$

where: K — coefficient of moisture absorption;

R_{60} — insulation resistance as measured by megohmmeter after 60 sec;

R_{15} — insulation resistance as measured by megohmmeter after 15 sec.

Damp insulation will have a coefficient value close to 1. As the insulation dries out, the coefficient rises and, when it becomes 1.3 or greater, the insulation is considered to be dry.

All insulation in a switchgear unit is also subjected to a test with d-c or a-c voltage. The magnitude of test voltage and the intervals

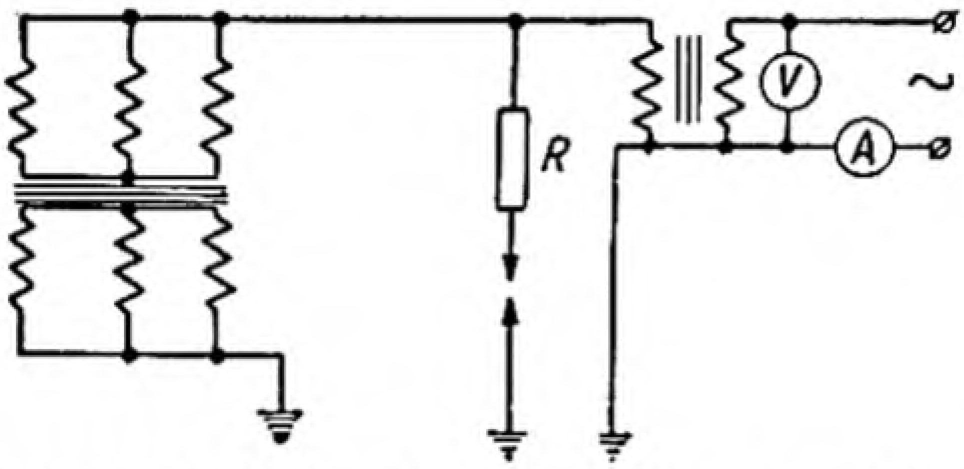


Fig. 300. Circuit for proof testing insulation with a raised a-c voltage

at which the tests are performed on the various units of switchgear, as well as on the substation as a whole, depends upon the working voltage, type and operating conditions of the insulation. The best results are obtained with a-c test voltages, because in such cases the voltage gradients in the insulation are closer to those existing during actual operation. These proof-test voltages are applied for one minute.

The proof-test circuit is rather simple and the same for all electrical equipment of a power station or a substation. Fig. 300 shows the circuit used for testing the main insulation of a voltage transformer with a-c test voltage. The windings should be tested one at a time, the remaining windings being shorted and earthed through the transformer core. The test voltage is applied to the shorted terminals of the winding to be tested (Fig. 300) from a special transformer in which one of the leads is earthed.

Faulty suspension and support insulators are detected while they are in service by measuring the voltage gradient across the individual units of a string or support insulator. This method uses a tester with a two-hook head (Fig. 301). The measured voltage distribution is then compared with characteristic curves plotted for

good insulators of the same type. The gradient will be lower across faulty units and higher across good ones. Fig. 302 gives the voltage distribution curves for a good 110-kv suspension insulator string (curve *1*) and for the same string when the fourth unit is injured (curve *2*).

An insulator unit requires replacement when the voltage across it drops by a third to half of its normal share.

The condition of oil-filled, compound-filled and bakelised-paper insulators and terminal bushings can be assessed on the basis of their dielectric losses. However, instead of dielectric loss which varies with the size of an insulator, it is more convenient to use what is known as the tangent of the loss angle or power factor which

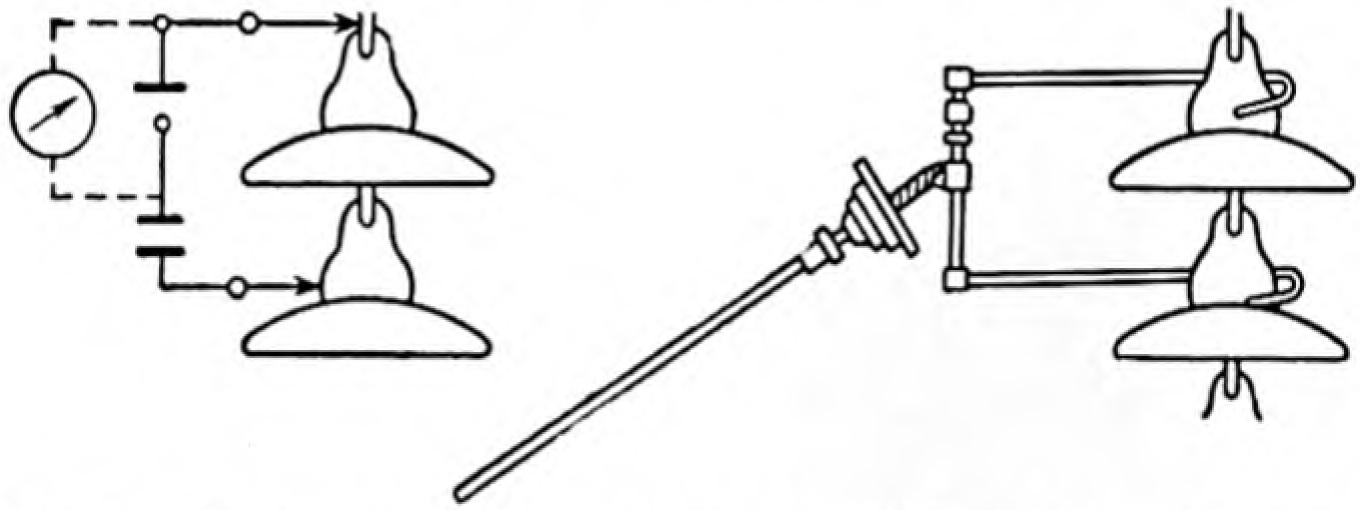


Fig. 301. Suspension insulators being tested with a special testing stick

is practically equal to the ratio of the leakage current to the capacitive current, or $\tan\delta=\frac{i_l}{i_c}$. The power factor is usually measured by suitable bridges.

The power factor provides a check on the ageing of laminated insulating materials. With time they begin to separate and form voids where air can appear and moisture will ingress. These and other changes impair the quality of laminated insulations, and their dielectric losses increase. The dielectric power factor test is obligatory for all oil-filled, compound-filled, and bakelised-paper terminal bushings and for other types of equipment. Bushings with an increased dielectric power factor should be replaced.

Preventive maintenance testing of switchgear equipment is usually scheduled as follows:

(a) on oil-blast and air-blast circuit breakers, their operating mechanisms, and remotely controlled operating mechanisms of isolators, concurrently with their overhauls;

(b) on oil-immersed tank-type instrument transformers, at least every three years;

(c) on cast-in-concrete reactors, coupling capacitors, static capacitors, at least every three years;

(d) on 6- and 10-kv pin-type insulators, bus bridges and ШТ-30 insulators, at least every year;

(e) on ШТ-35, ИШД-35 and ОС-1 pin-type insulators, at least every two years; and on other types of apparatus and suspension insulators, at least every 6 years.

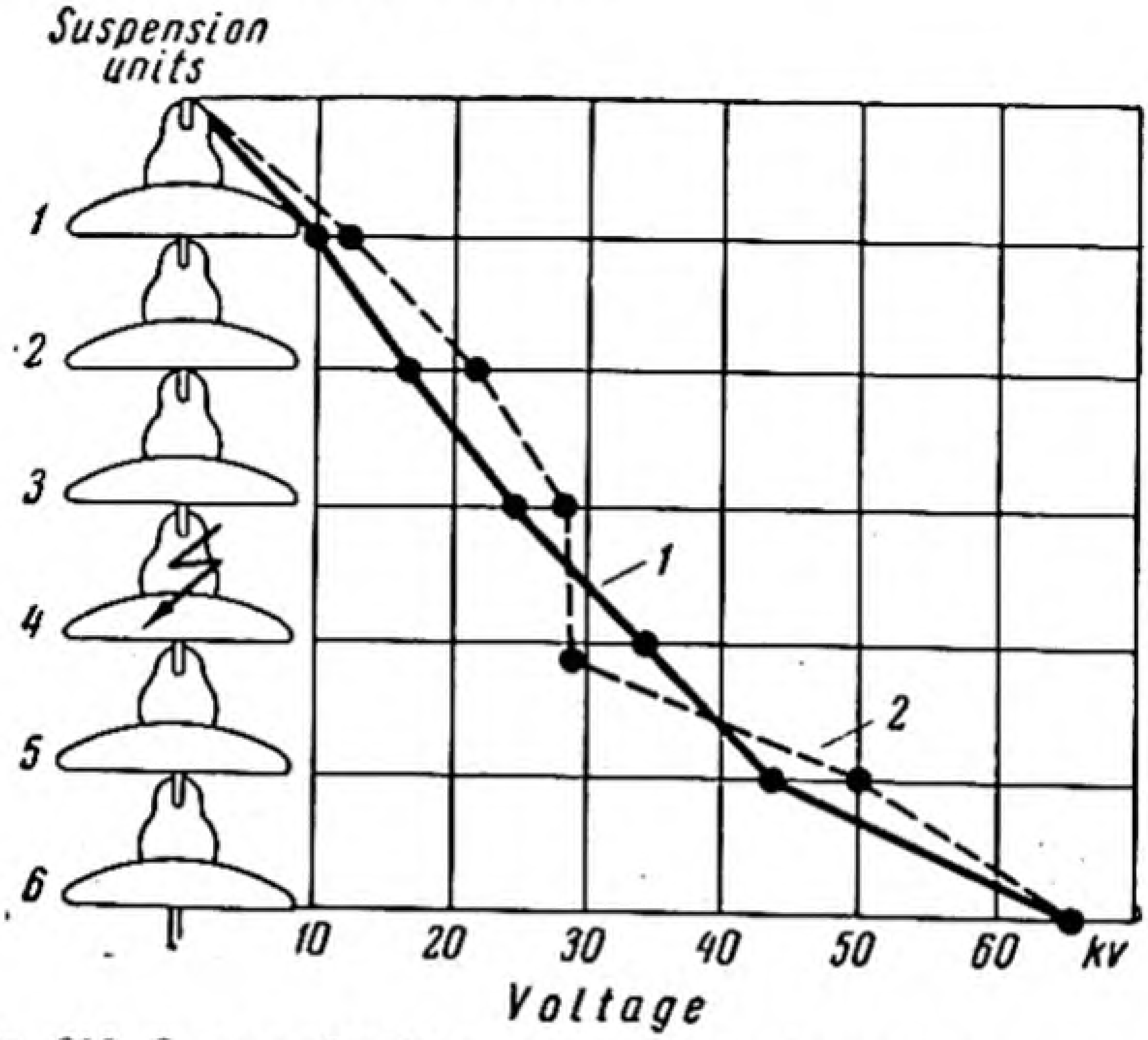


Fig. 302. Curves of voltage distribution along 110-kv suspension string for cases when the string is healthy and when the fourth unit in the string is defective

(f) on contacts, bus connections and connections to the apparatus, at least every 3 years.

Whenever defects are detected, the periods between preventive maintenance tests are shortened.

The emergency replacement stock of equipment, spare parts and components should be examined, tested, cleaned and lubricated every two years.

Switchgear equipment is subjected to the following tests.

All terminal bushings built with organic materials should be tested by the dielectric method. For terminal bushings rated for lower than 35 kv, these measurements are optional. The dielectric power factor at +20°C should not exceed the values listed in Table 31.

The insulation of a substation, with all the apparatus connected, is tested with a commercial-frequency voltage. The test voltage for

Table 31

Power Factor of Terminal Bushings and Insulators

Type of insulator or bushing	Dielectric power factor, per cent, for rated voltages (kv):			
	3 to 10	20 to 35	110	154 to 200
Oil-filled	—	—	2	2
Bakelised-paper	5	2.5	2	—
Bakelised-paper compound-filled	5	2.5	2	—
Compound-filled	3	2	2	—

each unit of a cemented post insulator and of a suspension insulator string should be 50 kv.

The insulation of circuit breakers, with the bushings in place, should be tested with the commercial-frequency test voltages given in Table 32, applied for one minute.

Table 32

Proof-test Voltages for Circuit Breakers of Various Ratings

Rated voltage of circuit breaker, kv	Test voltage for insulators, kv		
	for tests made together with breaker	for tests performed separately from breaker	
		outdoor equipment	indoor equipment
3	24	27	24
6	32	35	32
10	42	46	42
15	55	60	55
20	66	73	66
35	95	105	100
110	260	285	—
154	360	400	—
220	500	550	—

Busbar connections in outdoor switchgear and substations are tested by contact resistance measurements. The contact resistance of a busbar joint should be not greater than 1.2 times the resistance of the same length of the busbar proper.

In addition to inspection and insulation tests, switchgear equipment should also be tested for proper functioning and specified performance. Among other things, the apparatus should be tested for positive closing and opening under service conditions of control voltage and air pressure variations (where air-blast circuit breakers

are installed), for functional alignment of the associated assemblies in an apparatus, for the power or air requirements, etc. Tests and inspections, when thoroughly carried out, go a long way towards reliable and trouble-free operation of switchgear equipment.

66. Notes on Switchgear Repair

All repair involved in the maintenance of electrical equipment may be classed into routine (preventive-maintenance) repair and overhauls.

Routine repair is resorted to, above all, in order to remedy any defects or faults detected during inspections and, also, to locate and eliminate the causes of troubles observed in service.

Routine repair is usually carried out as the need arises. In addition, scheduled preventive-maintenance repairs are carried out at least once a year.

The preventive-maintenance repairs of substations and switchgear equipment include the following:

(I) a thorough visual inspection of the entire installation, cleaning of the equipment and also cleaning of the premises;

(II) checking of the fastenings and busbar clamps and joints for tightness; replacement of damaged insulators;

(III) cleaning and grinding of pitted isolator contacts, lubricating of contacts with petroleum jelly, trial closings and openings of single-pole isolators, checking of the blades in three-pole isolators for simultaneous closure, checking of operating mechanisms, adjustment and lubrication of pivot joints in isolators, tightening down of baseplates;

(IV) checking of draw-out chambers in metal-clad switchgear units, inspection and replacement of high-voltage fuses, when necessary;

(V) checking of earthing system and connections;

(VI) checking of protective relays and indicating-metering instruments;

(VII) sampling and replenishing of oil in all oil-filled apparatus.

Prior to an overhaul, an overhaul sheet is drawn up. This sheet lists all the abnormalities which must be remedied during the overhaul, and bills of the requisite spare parts, materials, tools, and fixtures are compiled.

Overhauls of substation equipment, including internal inspections, are generally scheduled at the following intervals:

(a) for oil circuit breakers, not less than every three years, and air breakers, two years. Depending upon breaker design, the number of operations it has performed, and the short-circuit power at the

11*

point of installation, the overhaul period may be extended. Unscheduled overhauls of oil-blast and air-blast breakers may be necessary after they have cleared more than four short circuits;

(b) for isolator remote-controlled operating mechanisms, not less than every three years;

(c) for oil-immersed tank-type instrument transformers, not less than every nine years.

The remaining switchgear equipment is given an overhaul when the preventive maintenance work shows the need for it.

A typical overhaul will include the following:

(I) an insulation test of bushings and internal insulation of circuit breakers, a check on the condition of their moving and fixed contacts;

(II) a check on the fixation of the contacts, arc-control chambers, and de-ion grids and their replacement when necessary;

(III) a check on the circuit-breaker operating mechanism, the springs, bolts, nuts, cotter pins; a check on the condition of the breaker mechanism; trial openings and closings of the circuit breaker; adjustment of the contacts for simultaneous closure; inspection of access covers, tanks, lifting mechanisms, gas vent assemblies and safety valves; inspection of the signal and auxiliary switch contacts and cams; a check on the breaker position indicators, cleaning and remounting of oil-level gauges, oil replenishment, replacement and purification;

(IV) a check on the moving and fixed contacts of load-breaking isolators for reliable fixation and simultaneous closure in all the phases; a check for proper entry of all the poles into their arc-extinguishing chambers; a feeler-gauge check for correct assembly of the arc-control chambers and for absence of gaps between the chamber halves; a check on the springs, bolts, nuts, and cotter pins; a check on the operating mechanism for overall condition and proper operation; inspection of the auxiliary switch contacts and cams; a check on the automatic tripping of the load-breaking isolator for operation in the event of a fuse blow-out.

As power circuit breakers are rather difficult to overhaul, a more detailed discussion follows.

67. Overhaul of a Type ВМГ-133 Minimum-oil Circuit Breaker

Disassembly. Prior to disassembly, the oil is drained from the pots through the oil drain openings *11* (see Fig. 71).

The flexible leads *13* and porcelain tie rods *11* (see Fig. 70) are removed, the clamping bolts *4* (see Fig. 74) are slackened, and the

pots are lifted off the support insulators one after another. For convenience, the pots should be hung and clamped on a special stand (Fig. 303); the bolts *3* (see Fig. 83) are then unscrewed, and the bushing insulator *15* (see Fig. 70) is taken off. The clamping bolts of the stop clamps *6* (Fig. 304) on bakelised-paper sleeve *7* are unscrewed to free the clamp and spring *5*, and the sleeve is taken out of the insulator.

Fig. 303. Stand for carrying out maintenance work on a ВМГ-133 breaker pot

The pots are then taken apart in the order illustrated in Fig. 71. All the parts of the circuit breaker should be placed on a suitable rack.

When the nut *15* holding the fixed cluster contact *1* in the pot is being unscrewed, the other two nuts used for securing the busbar to the cluster contact shank should be held against rotation with a spanner. This also protects the sealing gasket *13* from possible injury.

Insulator repair. The porcelain insulators and tie rods are inspected for the same defects as other porcelain parts. Damaged insulators and porcelain tie rods should be replaced.

The upper and lower leather collars *8* and *9* (see Fig. 304) are then examined. If heavily worn, the collars should be replaced.

The internal surfaces of the bushing insulators and the bakelised-paper sleeves taken out of them are now washed with clean transformer oil, wiped dry, and the bushings completely reassembled.

The nuts *1* (see Fig. 74) are then tightened on the bolts *2* which hold the support insulators on the circuit-breaker frame.

Repair of contacts. If only slightly fused, the tips of the contact rods *12* (see Fig. 70) are smoothened with a file. When considerably fused, they should be replaced. To do so, the tip is clamped in a vise and the rod is screwed off it. A new tip is then matched to the contact rod, their edges are trimmed at the joint, and the tip is centre-punched at three points round the circumference of the joint.

To disassemble the cluster contact, the screws *3* (Fig. 305) holding the finger back-up springs under the laminate insulation ring *4* are unscrewed, and then bolts *5* which secure the contact fingers *1* to the body are backed out. The fingers are marked for identification

on reassembly and removed for cleaning with a file. Heavily pitted fingers should be replaced. The pressure of the back-up springs is checked and the laminate insulation ring 4 is examined. Deformed or broken rings are replaced.

The repaired contacts are washed in petrol and wiped dry.

Arc-control chamber repair. The arc-control chambers 9 (Fig. 71) should be removed from their pots, carefully inspected, and cleaned of carbon deposits and dirt. All openings, clearances and gas vents are then examined. In the case of heavy damage, including marked pitting, deformed openings and vents, the chambers should be replaced.

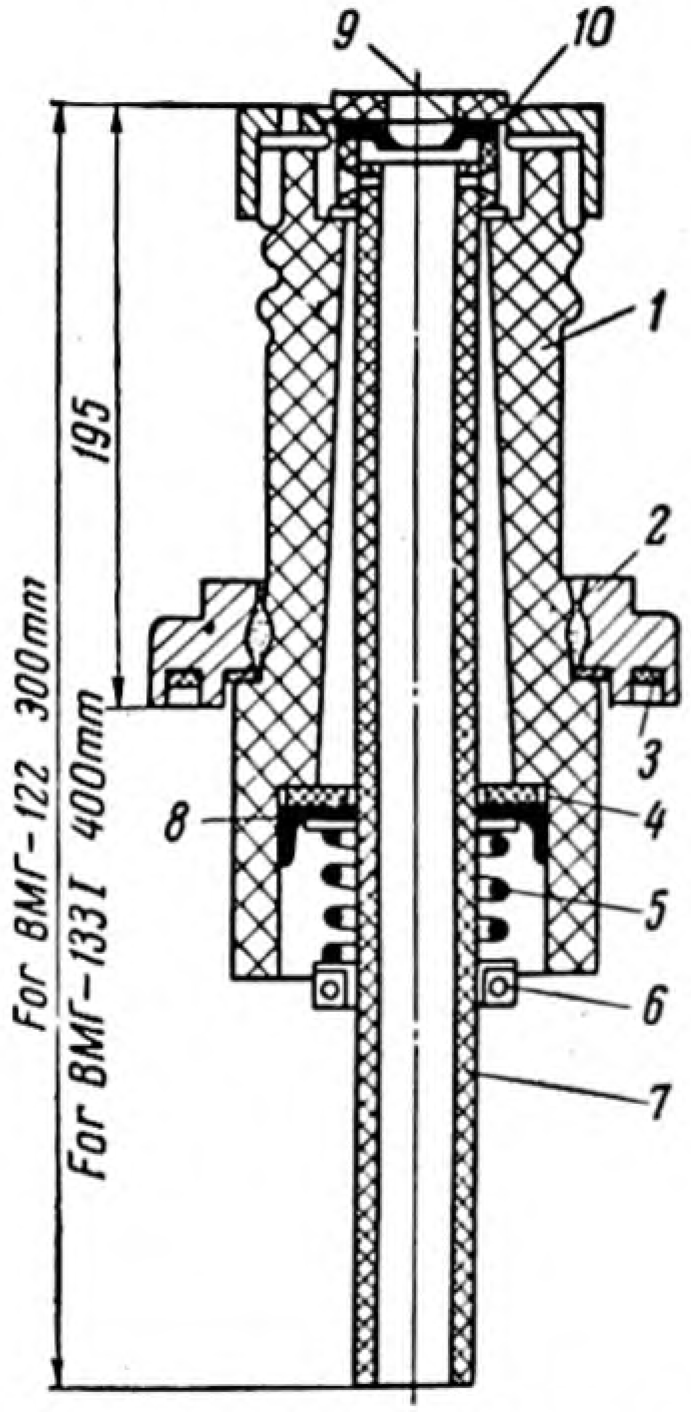


Fig. 304. Bushing insulator of the BMГ-133 circuit breaker:

1—porcelain bushing; 2—cover-flange; 3—sealing gasket; 4—bakelised-paper ring; 5—compression spring; 6—bolted stop clamp; 7—bakelised-paper sleeve; 8—lower leather collar; 9—upper leather collar; 10—cap

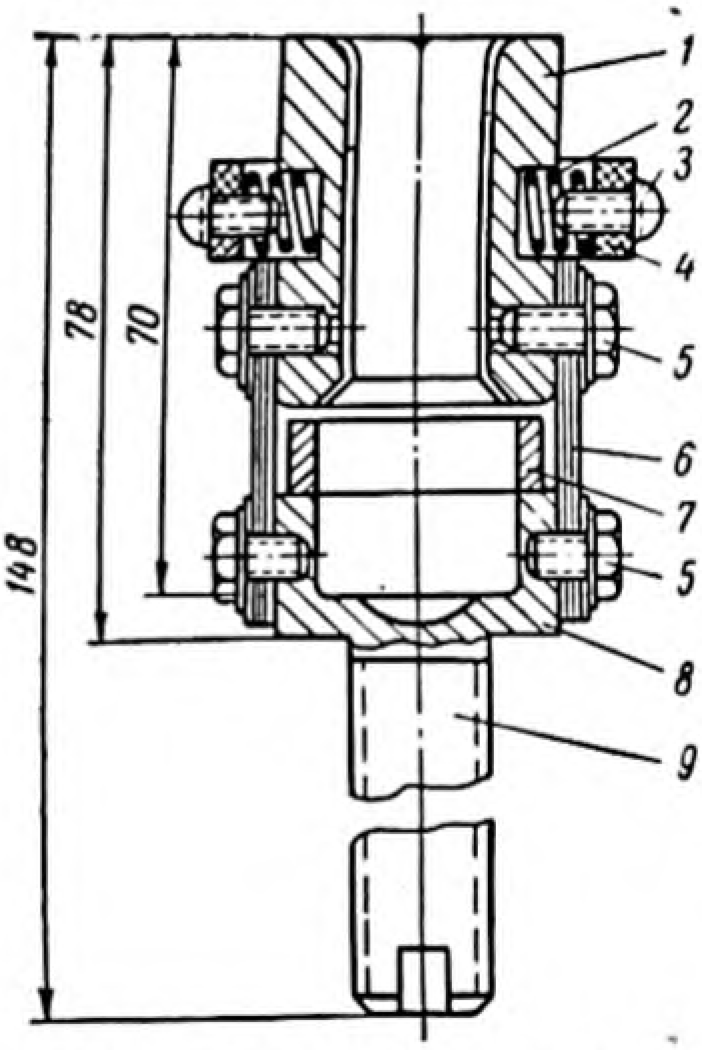


Fig. 305. Cluster contact of BMГ-133 circuit breaker:

1—finger plates (segments); 2—finger back-up springs; 3—screws; 4—laminate-insulation back ring; 5—bolts for securing finger plates; 6—flexible jumpers; 7—stop ring; 8—contact body; 9—shank of contact

Arc-control chambers fit for further use should be cleaned and washed with transformer oil.

Bakelised-paper sleeves 8 are then cleaned of traces of carbon deposits in the same way as the arc-control chambers 9. The damaged varnish coating is re-touched by applying a coat of air-drying in-

sulating varnish. Whenever through holes, cracks or scorched paper are detected in a sleeve, it should be replaced.

Special attention should be devoted to proper operation of the ball valve *2* (Fig. 71). Under normal atmospheric pressure it should pass the oil from the pot into the reservoir, but must fully close the opening when the pressure rises.

The oil gauges, and filler and drain plugs should be cleaned and tested for proper functioning and tightness. The oil gauge should be examined for communication with the oil reservoir. To do this, some oil should be poured into the pot through the oil-filling hole. If after a short time the oil level in the gauge and the pot becomes equal, the oil gauge and the valve function properly.

Repair of the operating mechanism. The operating mechanism or linkage is given a detailed inspection and cleaned, the rubbing parts lubricated, the paint re-touched and all the fastenings checked for tightness.

To begin with, the bearings of the circuit breaker shaft *7* (Fig. 70) are checked for excessive friction or binding. To do so, the tie rod of the operating mechanism is disconnected from the lever *8* on the circuit-breaker shaft, and the circuit-breaker shaft is turned by hand. Binding indicates that the breaker frame is out of alignment.

The breaker opening springs should be checked with special care in both the closed and opened positions and also while slowly closing and opening the circuit breaker. The spaces between the spring coils must be equal in all cases. Slackened springs should be replaced.

The spring buffers and oil dashpots are checked in practically the same manner as during breaker installation (see Fig. 81).

In the case of binding or seizure in the oil dashpot it should be taken apart and washed with transformer oil. When necessary, the surfaces of the piston and cylinder should be smoothened with fine-grained emery paper. The dashpot is then re-assembled and filled with clean transformer oil to 10 mm above the piston.

The spring buffer should be cleaned of the old lubricant, and the springs and the rod lubricated with petroleum jelly or antifreeze grease.

Re-assembly of the circuit-breaker pots. The pots are re-assembled in reverse order. First, the seating surfaces of the fixed contact base and the pot receiving the gasket *13* (Fig. 71) should be cleaned and given a coat of glyptal varnish; the cluster contact is then put in place, taking care to screw its nut on as tightly as possible.

In mounting the arc-control chamber, care must be taken to adjust the distance between its bottom surface and the top of the cluster contact (distance *D* in Fig. 306), so that it is 2 to 4 mm in ВМГ-133-I breakers and 14 to 16 mm in ВМГ-133-II and ВМГ-133-III breakers. For this purpose, the distance from the contact fingers

to the upper end of the steel pot (dimension A) is measured, then the height of the arc-control chamber when it is still out of the cylinder (dimension B) is found. The chamber is now put into the pot and the distance from the chamber to the top end of the pot (dimension C) is measured.

The distance between the chamber and the cluster contact (dimension D) can now be determined: $D = A - (B + C)$.

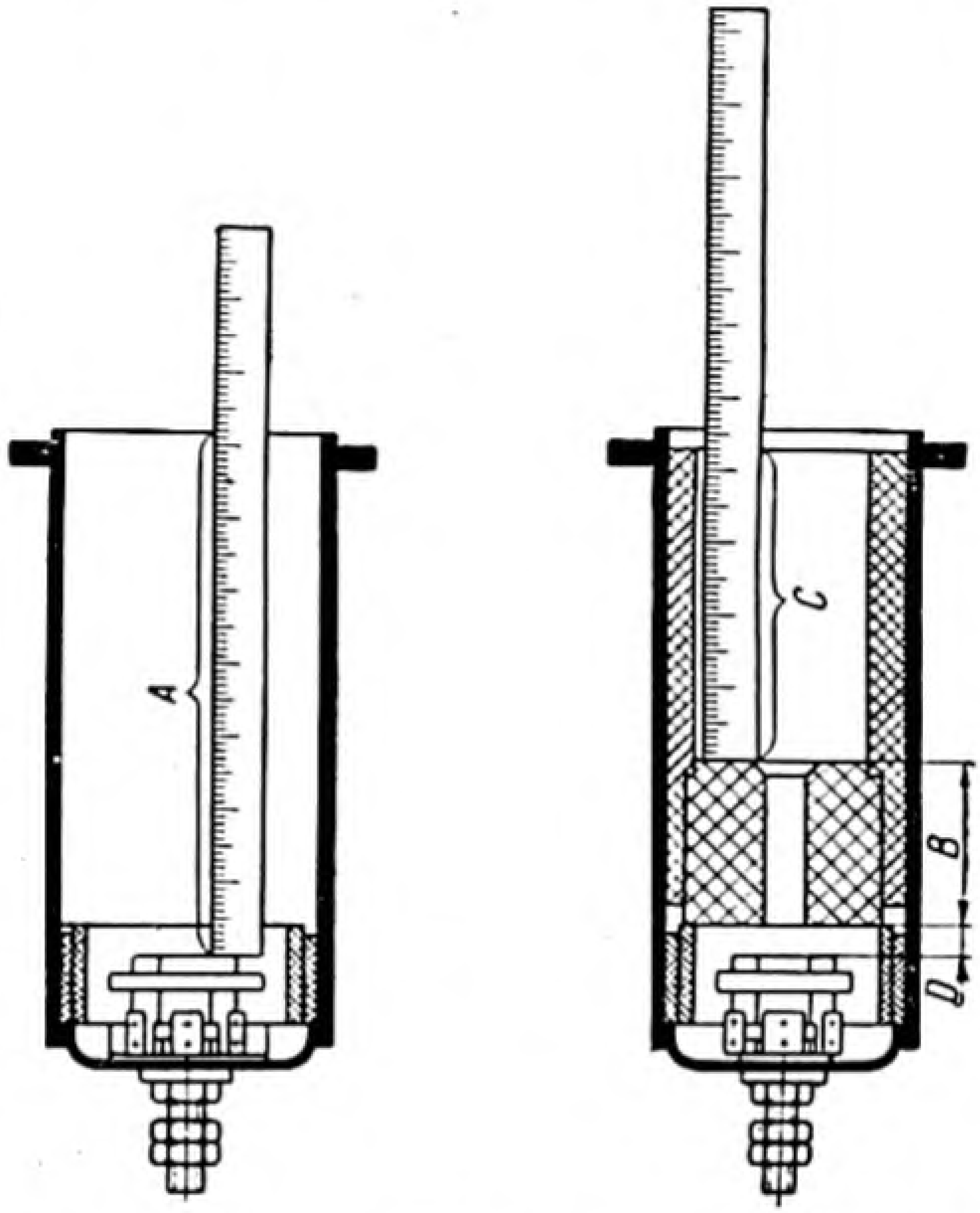


Fig. 306. Fitting of arc-control chamber in ВМГ-133 circuit breaker pot

The actual dimension D can be adjusted by inserting pressboard spacing rings between the plywood ring *12* and the pot *10* (Fig. 71), or by reducing the height of the plywood ring.

The arc-control chamber should be set up so that the gas vents will face towards the support insulators.

The bakelised-paper distance sleeves *8* should be put into the breaker pots so that their openings and slots are in line with their counterparts in the steel pots and their top ends are 2 to 4 mm below the edges of the steel pots (Fig. 306).

In assembling the bushings, care must be taken to mount the bakelised-paper sleeve *7* (Fig. 304) so that the distance from the top

cap *10* to the end of the tube is 400 mm (depending on the model of the circuit breaker).

The sealing ring *3* in the groove of the bushing cover should be cleaned and given a coat of thick bakelite varnish. The bolts of the cover should be tightened uniformly, giving a turn to each one across from the other so that the bushing will not be misaligned relative to the steel pot.

The contact surfaces of the flexible connections and the contact-rod lug should be thoroughly cleaned with fine-grained emery cloth and given a thin coat of petroleum jelly prior to assembly of the pots.

After the contact rod has been inserted in its pot, it is lifted to a height corresponding to the open position of the breaker and allowed to fall in order to check it for seizure or binding in the same manner as when installing such a circuit breaker for the first time (see Sec. 14).

The assembled breaker pots are mounted on the support insulators, and the breaker is aligned as during the original erection.

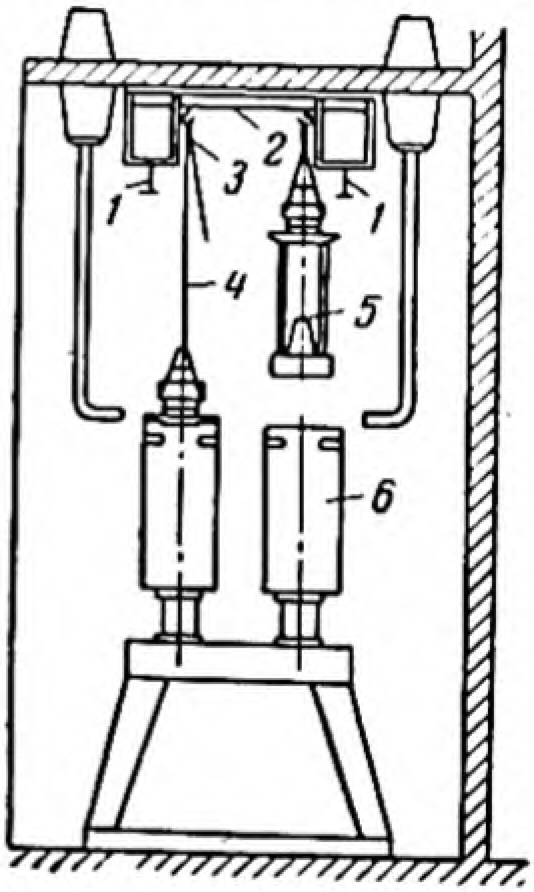


Fig. 307. Lifting of internal parts of breaker pot: *1*—cross beams; *2*—jumper beams; *3*—tackle block; *4*—sling; *5*—internal part of pot; *6*—circuit breaker pot

68. Overhaul of a Type МГГ-229 Oil Circuit Breaker

Disassembly. The insulating interphase barriers *7* (Fig. 98) are removed first and then the gas manifold is detached from the circuit breaker and pushed aside to the cell side wall where it is tied to the ceiling beams. In order that the gas manifold can be swung out of the way, its joints should be loosened, and the manifold turned about the branch pipe.

Next the busbars are disconnected from the circuit breaker, jumper beams *2* (Fig. 307) are placed between the cross beams *1*, blocks *3* are attached to the jumper beams and further disassembly is continued as in the initial inspection prior to installation (see Sec. 16).

Repair of contacts and arc-control chambers. The contacts and arc-control chambers are repaired after the breaker has been disassembled.

If the main contacts show signs of slight fusing and pitting, the rough spots may be smoothed down with a file. All contacts which have considerably damaged surfaces should be replaced.

The contact rods are repaired in the same manner as the contact rods of a ВМГ-133 oil circuit breaker.

When damage is detected on the fixed cluster contact, it should be removed with a special spanner and disassembled.

The contact fingers with slightly damaged surfaces are simply cleaned smooth, while those with a heavily pitted surface, as well as all contact back-up springs unfit for further service, should be replaced.

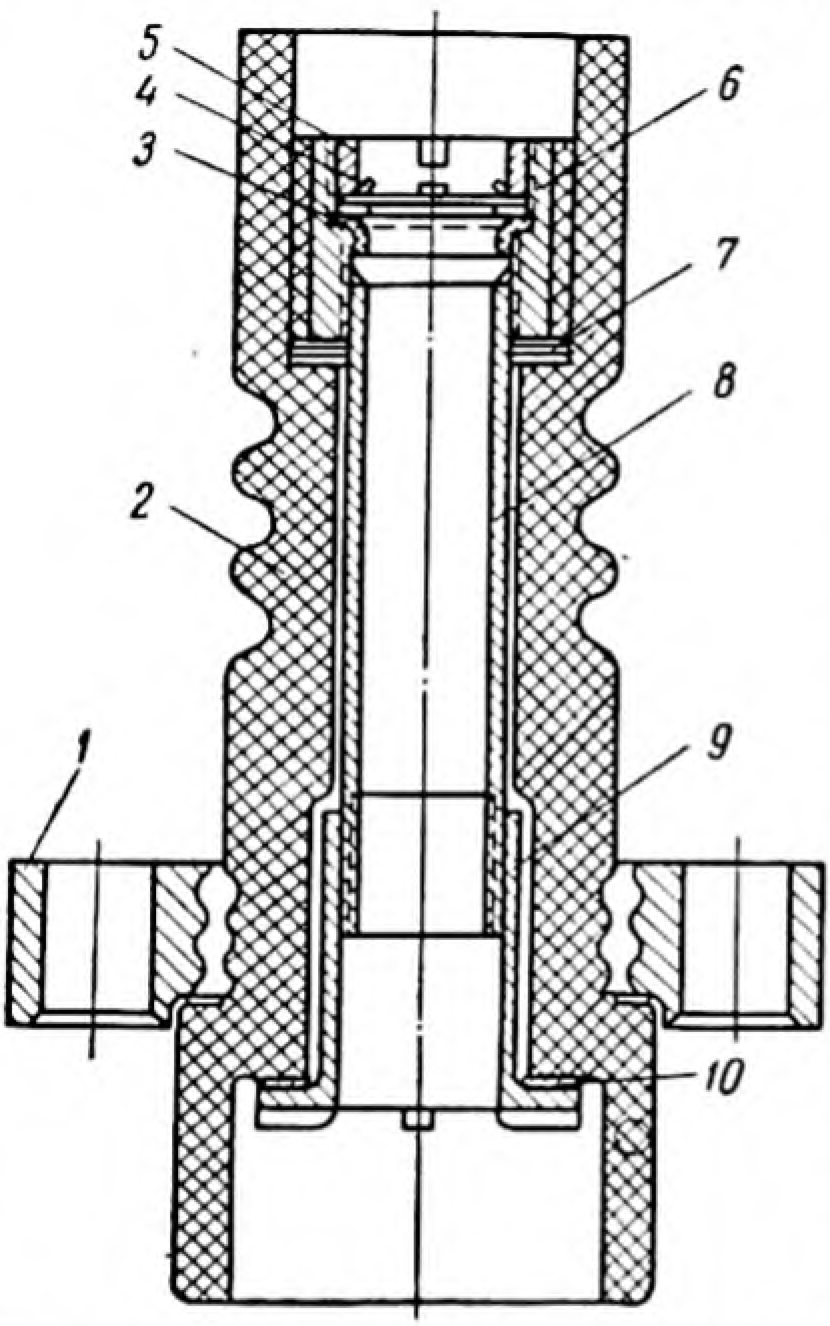


Fig. 308. Bushing insulator of the МГГ-229 circuit breaker:

1—flange; 2—porcelain bushing; 3—collar; 4—contact ring; 5—round clamping nut with outside thread; 6—upper flange of copper tube; 7—electrical pressboard washer; 8—copper tube; 9—lower flange of copper tube; 10—aluminium washer

The arc-control chambers are repaired in the same manner as the chambers in ВМГ-133 oil circuit breakers.

Insulator repair. Bushings are inspected and cleaned with clean soft rags moistened with petrol. Simultaneously the leather collar *3* (Fig. 308) which serves as a seal in the upper part of the bushing is examined. If the collar is damaged, it should be removed after unscrewing the clamping nut *5* and the contact ring *4*, and then replaced. The new collar should be placed so that it and the lugs of the contact ring fit closely to the rod passed through the bushing. With the collar in place, the nut *5* is tightened snugly.

Concurrently, the cemented joints between the insulators and their mounting flanges are examined and given several coats of glyptal varnish.

Where some of the cement has crumbled out, it should be patched up. If an insulator has to be entirely re-cemented, it should be sent to a repair shop.

Support insulators should be replaced as described below.

A chain hoist of 0.5-ton capacity is suspended from the cross beam *1* (Fig. 309) and the necessary pot is lifted off after loosening the clamping ring *8* (Fig. 310). With the cylinder lifted out of the way with the hoist, the bolts which secure the upper flange *5* are unscrewed and the insulator is removed. The head *7* is then taken off

from the insulator by clamping the latter in a vise to unscrew the bolt *1* with a box spanner.

When mounting the head piece on the shoulder of the insulator, the upper flange *5* and electrical pressboard gaskets *3* are first put in place, the bolt *1*, complete with a steel washer and the necessary gaskets, is inserted and screwed down as tightly as possible. Next comes the assembled insulator, which is set up on the lower flange *4*

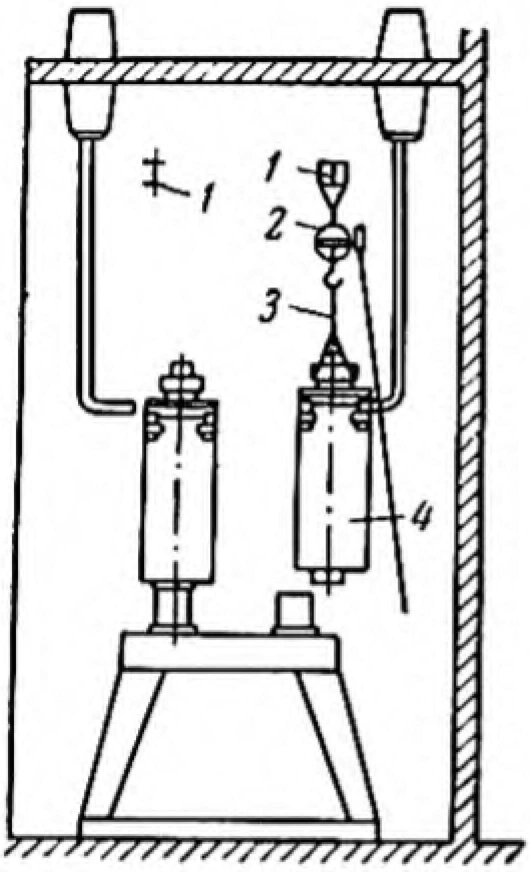


Fig. 309. Removal of a breaker pot:

1—cross beams; *2*—chain hoist; *3*—sling; *4*—breaker pot

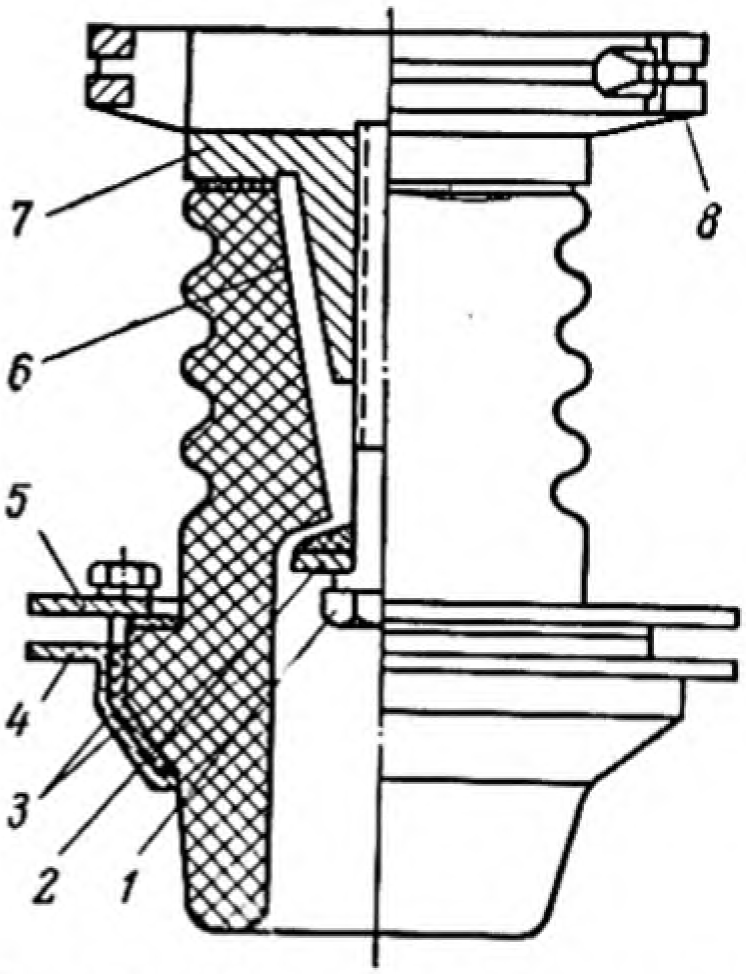


Fig. 310. Pot support insulator of the МГГ-229 circuit breaker:

1—bolt; *2*—steel washer; *3*—gaskets; *4* — lower flange; *5* — upper flange; *6* — porcelain insulator; *7*—head of insulator; *8*—clamping ring

after placing electrical pressboard gaskets on the flanges. The insulator is then secured in place with bolts and lock washers.

Gas vent repair. To take apart the gas vent system, the lock nuts *9* (Fig. 311) are unscrewed on the pressure studs and the studs are driven as far as possible into the oil-baffle pipe elbows, after which the oil-baffle pipes can be removed. The porcelain balls or pebbles filling the pipes are then washed, and all the other parts of the oil-baffle assembly are cleaned. If the porcelain adapter *4* has to be replaced, it is essential to provide a tight joint between the adapter and the bakelised-paper tube *2*.

The further assembly and mounting of the oil-baffle in the gas vent piping is carried out in the same order as when the circuit breaker is first installed (see Sec. 16). The joint between the oil-baffle sys-

tem and its base *1* should be sealed with bakelite varnish to make it tight.

The circuit breaker is adjusted and prepared for service in the same way as when newly installing it.

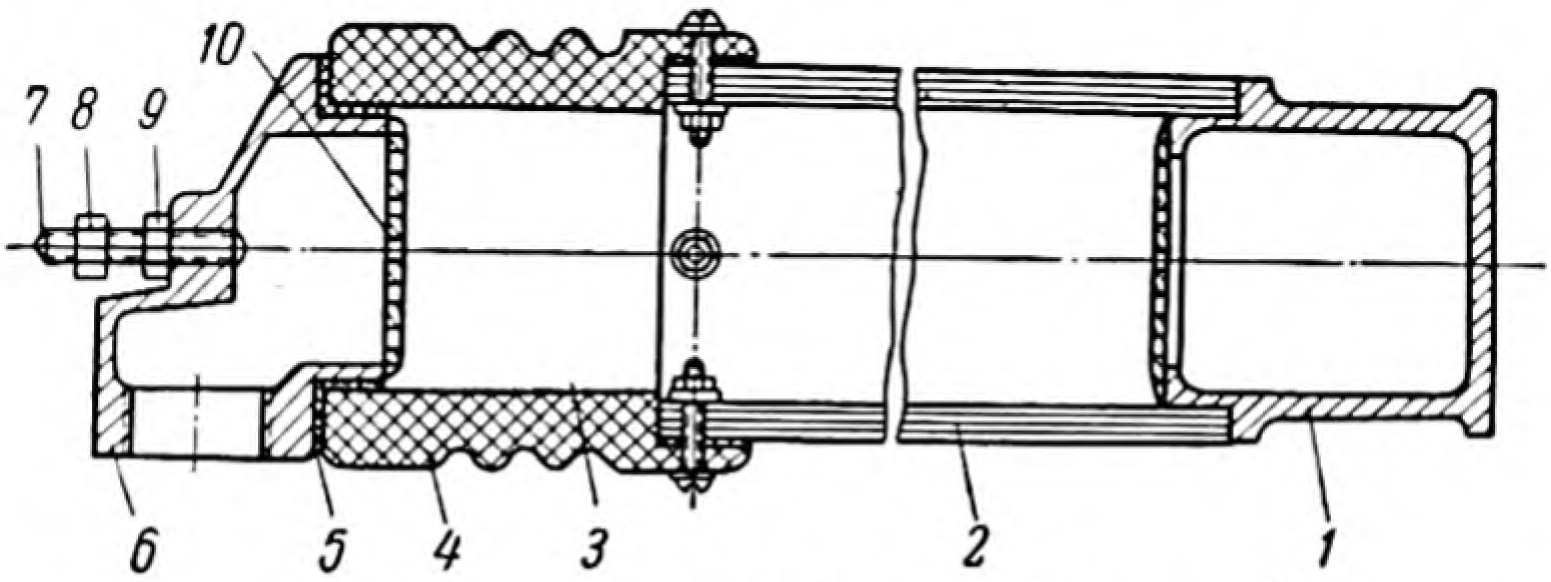


Fig. 311. Oil-baffle assembly:

1—base; *2*—bakelised-paper tube; *3*—space filled with porcelain balls or pebbles; *4*—porcelain adapter; *5*—gasket; *6*—elbow; *7*—pressure stud; *8*—nut on pressure stud; *9*—lock nut; *10*—baffle screen

69. Overhaul of Type ВМ-35 and ВМД-35 Oil Circuit Breakers

Disassembly. To begin with, the oil should be drained from the breaker tanks through oil-drain valves *1* (see Fig. 170), and the breaker brought into the open position.

The tanks are then lowered and removed, the internal parts of each circuit breaker are inspected after removing the shields *3* which seal off the axial-blast chambers and the metallised shield surfaces are inspected. If they are damaged, tin-plate linings should be attached to the shields.

Now the rods *16*, guide tubes *4*, axial-blast chambers *14* and actuating linkage *8* are wiped with clean rags, while examining the insulating parts of the circuit breaker for scratches and raised laminations.

At this time, also the cross-arm *2* carrying the moving contacts is checked for reliable fixation to the lift rod *16*, which, in turn, should be securely attached to the breaker mechanism. If the moving contacts are pitted, they should be smoothened with a file. Contacts which are heavily damaged or have been filed down several times during previous repairs should be replaced.

The axial-blast chambers are then dismantled, their parts are washed with transformer oil, and the pots are reassembled. If the chambers have textolite or metal bolts, they should be replaced with wooden components. The fixed contact should be smoothened if

slightly pitted, or replaced. All back-up springs in the fixed contacts which have lost their resilience should also be replaced.

The current transformers are then checked for fixation, the plywood tank insulation is examined; it should not have any metal nails on its surfaces (except for its upper and lower parts).

The circuit breaker is closed and opened manually for a check on its mechanism which should show no signs of significant friction or binding.

A defective terminal bushing, if any, should be replaced. To do this, the axial-blast pots and the current transformer should be removed, following which the bolts securing the bushing to the top plate of the circuit breaker should be unscrewed.

The position of the bushing being installed is adjusted by proper tightening of the bolts on the flange. It is essential to set the bushing in line with the other bushings.

Concurrently with the breaker repair the operating mechanism should also be inspected and repaired.

After the repair, the circuit breaker and its operating mechanism are separately checked for unobstructed operation and absence of binding. Special attention should be paid to the shafts which couple the circuit breaker and operating mechanism. They should be free to be rotated by hand and not be bent. If the breaker mechanism or its operating mechanism binds, the cause of binding should be eliminated. If the binding is due to misalignment of the bearings, they should be centred by adjustment with shims. At the same time, the joint coupling should be examined for proper assembly and mounting.

After the repair, the circuit breaker should be adjusted for joint operation with the operating mechanism in the same manner as when the circuit breaker is first installed (see Sec. 28).

70. Overhaul of an МКП-35 Oil Circuit Breaker

The overhaul of an МКП-35 oil circuit breaker follows the same general lines and consists of the same operations as that of ВМ-35 and ВМД-35 oil circuit breakers, for they are similar in design.

In МКП-35 circuit breakers the moving contacts have threaded detachable tips which, when heavily pitted, can be easily removed for replacement.

During the repair of the МКП-35 bushings, it is very important to check their filling compound *12* (see Fig. 184) for overall condition and the upper seal for tightness. For this, the bushing is taken apart by unscrewing the nut *4*, removing the connector lug *5* and cap *7*, and taking off the cover *10*. The filling compound should

be free from cracks. Its level should be sufficient to cover the end of the bakelised-paper tube but should at the same time be within about 20 mm of the edge of the porcelain shell.

In assembling the upper sealing joint, it is essential that the rubber gasket *2* under the cover *10* is placed properly and that the bushing conductor rod *13* is tightly sealed.

The lower bakelised-paper sleeve of the bushing should be checked for scratches, cracks or raised layers.

The bushings should be checked for fixation to the breaker top plate by tightening the bolts while taking care not to change the angle at which they have been set up by the manufacturer.

Bushings with cracked or chipped porcelain, compound leaks or diluted compound should be replaced.

71. Overhaul of an МГ-110 Oil Circuit Breaker

To begin with, the oil is drained and the arc-control device is taken apart.

For this, the relief valves *13* (Fig. 200) are taken off, the pipe inserts *14* (absent in breakers made after 1957) are pulled out, and the bolts *11* fastening the housings *15* to the flanges of the porcelain shells *8* are removed. The flexible connections are disconnected from the covers of the arc-control devices, and their housings are lifted off.

Next the spring valves *12* are removed, the nuts holding the arc-control devices are unscrewed, and the inner assemblies are taken out of their sleeves *7*. If these assemblies are difficult to pull out, it will be a good plan to close the breaker slowly with a screw jack, and the contact rods *18* will do the job.

The inner assemblies and bakelised-paper sleeves are thoroughly cleaned of all deposits and metal particles, using clean lint-free rags moistened with petrol for this purpose. Special attention should be paid in cleaning the barriers *16* in the detachable parts near the arc-control vents and the inside of the vents.

At the same time the external surfaces of the bakelised-paper sleeves *7* and the internal surfaces of the porcelain shells *8* are cleaned, using a steel rod with a rag wrapped around its end for this purpose. For cleaning, the rod should be inserted between the porcelain shell and the bakelised-paper sleeve.

After they have been cleaned of carbon deposit, the spring valves *12*, inside tubes *14* and housings *15* are washed with clean oil.

The pitted contacts are smoothened with a file, wiped with a clean rag, and given a thin coat of petroleum jelly.

Even though not fused, the kirite alloy contact tips should be smoothened with a file just prior to filling the circuit breaker with oil.

The distance between the fixed contacts *10* and intermediate contacts *17* in the inner assembly of the arc-control unit should conform to the dimension 47 mm, accurate to within —1, or +2 mm. If it does not, it must be attained by replacing the fused or worn contacts.

Then the inner assemblies of the arc-control devices (without their spring valves) are put in place, and the travel of the moving contacts inside the fixed contacts *10* is checked. To do so, the inner assembly is secured in place for the time being with two nuts across the cover (at top and bottom), and the distance is measured through the opening *A* (Fig. 312) in the cover *1* between its surface and the head of the bolt *9* to which the fixed contact *7* is attached. The measurement is taken in both the closed and open position of the breaker. The difference between the two measurements is the travel of the moving contacts inside the fixed ones and should be 15^{+1}_{-2} mm. To avoid mistakes in measurement, the end of the measuring rod should be thrust up against the bolt head or the bottom of the slot in the bolt head in both measurements.

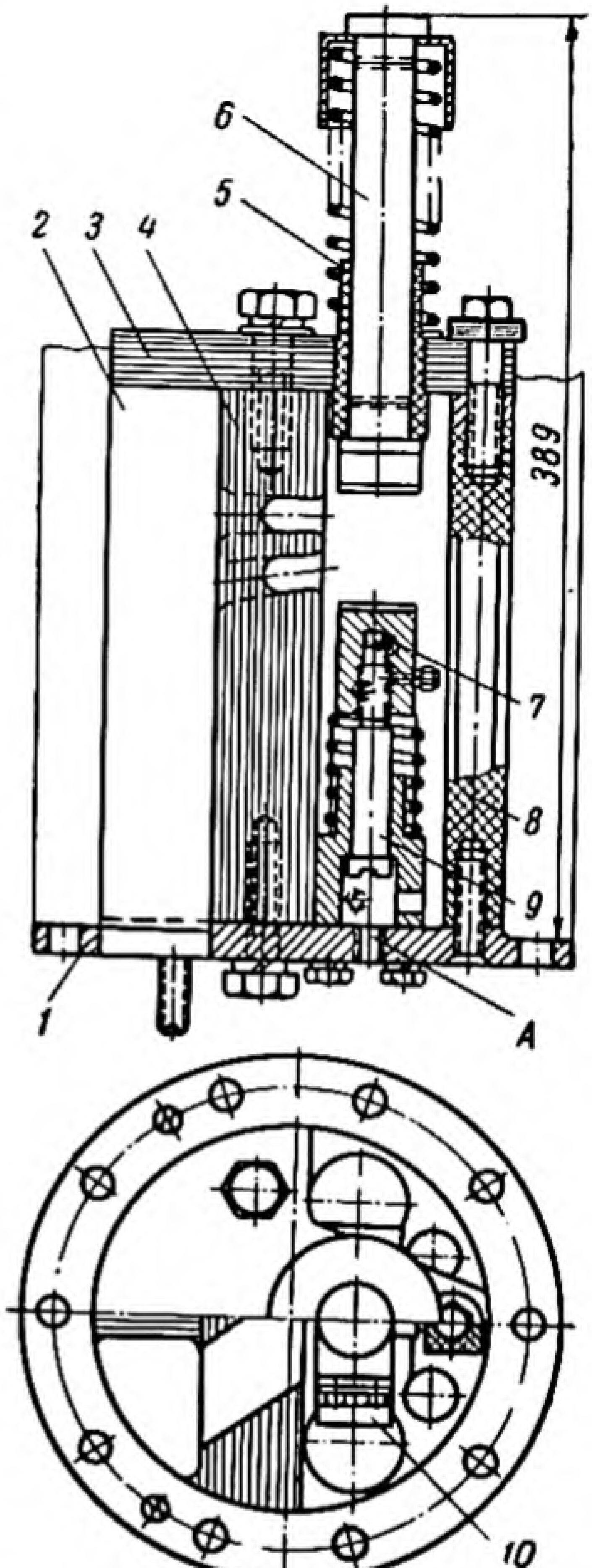


Fig. 312. Detachable part of arc-control unit in МГ-110 circuit breaker:

1—steel copper-metallised cover; *2*—textolite partition; *3*—textolite disk; *4*—textolite barrier; *5*—textolite sleeve; *6*—intermediate contact; *7*—fixed contact; *8*—textolite distance piece; *9*—bolt; *10*—flexible connectors

If this in-contact travel of the contacts is other than specified, the moving contact rod should be adjusted. For this, the breaker mechanism cover is removed, the nut locking the clevis *4* on the rod *3* (Fig. 200) unscrewed, the pivot joining this clevis and the mechanism lever pulled out, and the clevis screwed on or off until

the necessary length is obtained. The clevis and lever are coupled again, and the clevis is locked with the nut.

If the moving contact rods are heavily pitted and their threaded ends cannot be screwed into the toggles deep enough for adjustment

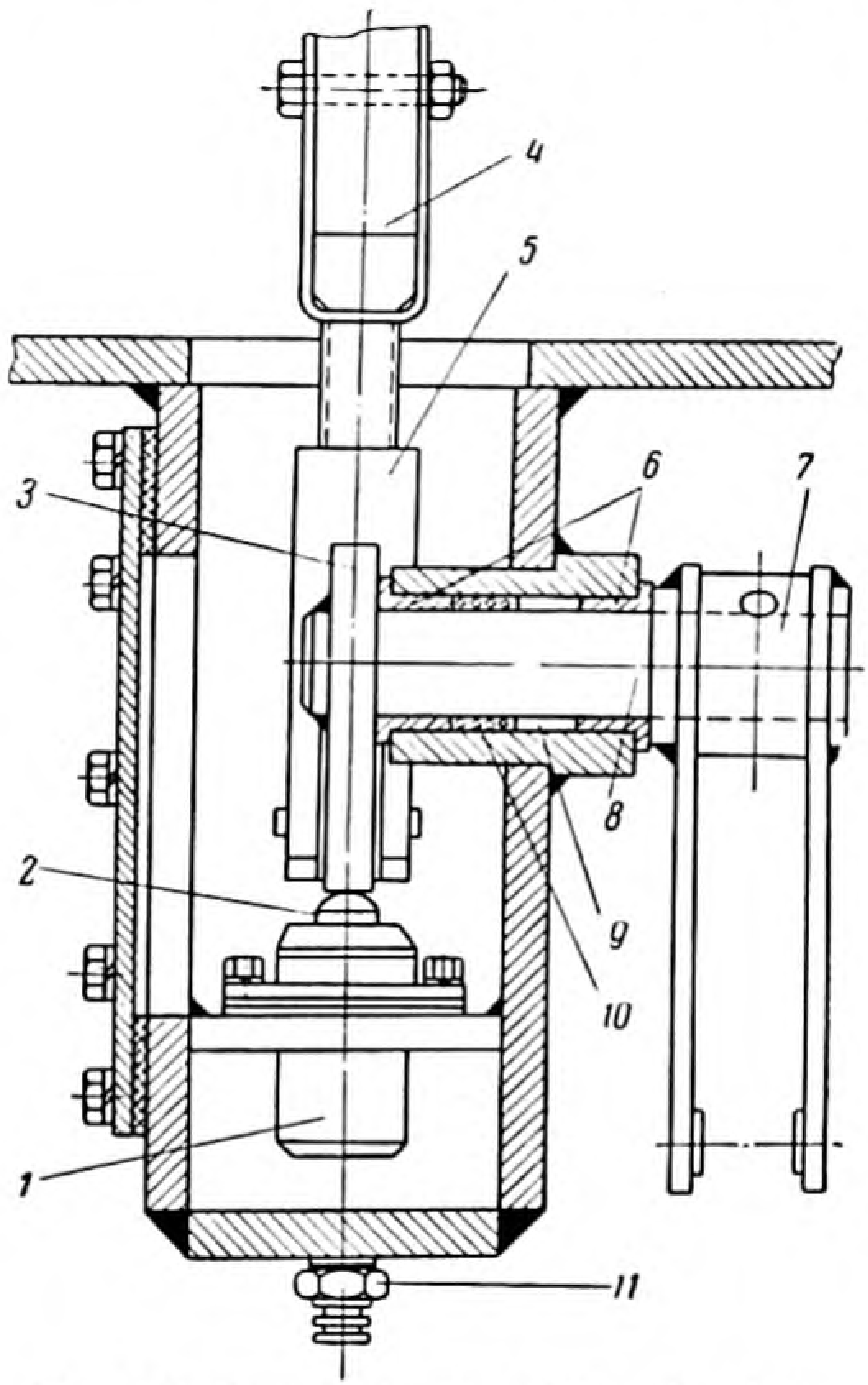


Fig. 313. Lower actuating linkage housing:

1—oil dashpot; *2*—oil dashpot piston rod; *3*—internal lever (welded to shaft); *4*—lower end of insulating rod; *5*—clevis screwed on lower end of insulating rod; *6*—brass bushes; *7*—double-arm lever for connecting interpole tie rods and operating-mechanism tie rod; *8*—shaft; *9*—packing of asbestos yarn impregnated with graphite lubricant; *10*—spring; *11*—oil drain plug

(less than 10 mm), they should be replaced. To accomplish this, the cover carrying the oil gauge *19* (Fig. 200) is removed, the nuts locking the clevises *4* are unscrewed, the pivot pins are pulled out,

the clevises are screwed off, and the levers to which they are coupled are removed.

The pitted contact rods are then taken out for replacement by withdrawing them from the openings in the flanges *6*, turning their free ends downward, and pulling them out together with their flexible connectors *20*, through the top access opening in the linkage housing. Next the push rods are removed, for which purpose the pin *1* (Fig. 203) connecting the upper end fitting of the rod with the shackles *2*, and the pin joining the clevis *5* and rod *4* (Fig. 313) with the internal lever *3* are pulled out; the push rod and clevis together are taken out through the top access opening in the linkage housing. The position of the clevis on its push rod end fitting should be marked to facilitate reassembly and to avoid readjustments of push rod length.

Such an overhaul may involve temporary removal or replacement of a porcelain shell. Before the shell may be put back in place, it should be washed with petrol and its rubber gasket should be given a coat of varnish. The shell should be mounted so that the largest clearance between it and the bakelised-paper sleeve is at the bottom.

To avoid any damage to the porcelain, nuts holding down the shell should be tightened uniformly round the bolt circle.

Sometimes it may be necessary to replace a bakelised-paper sleeve (Fig. 314). The new one should be set up so that the three textolite lugs *4* receiving the studs *5* are in the upper part of the open end of the sleeve.

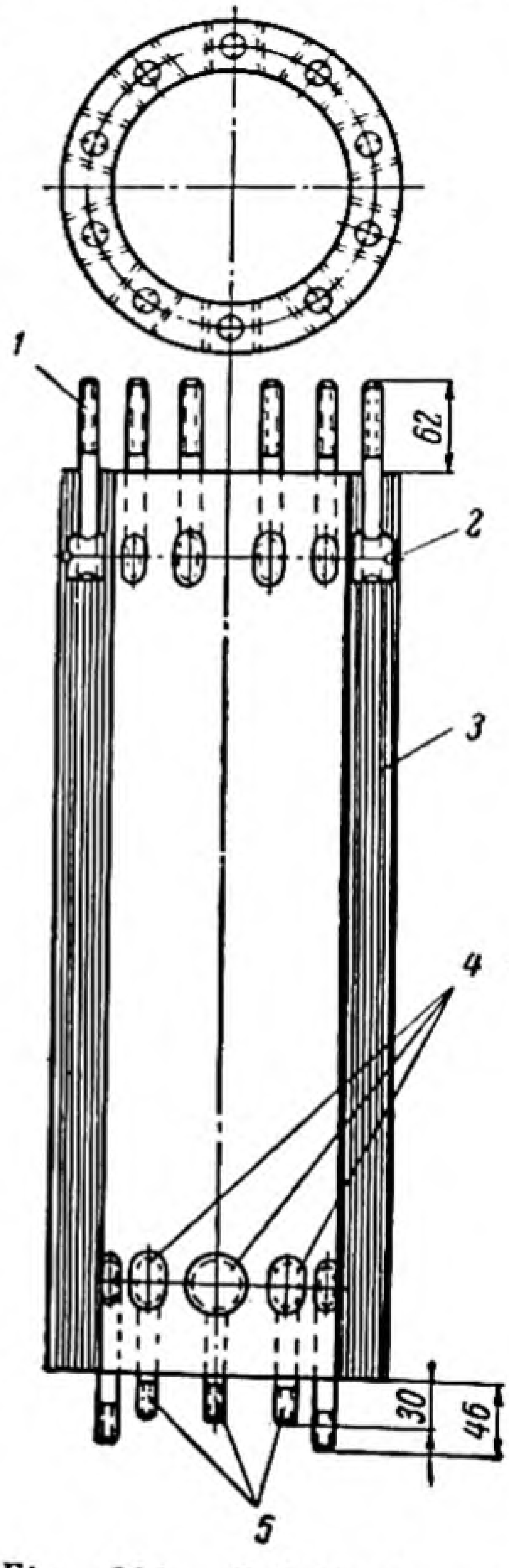


Fig. 314. Bakelised-paper sleeve of arc-control unit:
1—steel studs; *2*—steel lugs; *3*—sleeve; *4*—textolite lugs; *5*—studs

During an overhaul it will be good policy to inspect the small wiring conductors and terminals, remove traces of fusion from the contacts of the control contactor, examine and apply a coat of petroleum jelly to the auxiliary contacts.

72. Overhaul of an MKП-110 Oil Circuit Breaker

Before an MKП-110 oil circuit breaker can be overhauled, the oil should be drained from its tanks by connecting the drain cocks to the oil piping with a flexible hose and then opening the oil-drain cocks.

After the oil has been drained, the covers on the tank manholes *6* (Fig. 206) are unbolted to obtain access to the internal assemblies and parts of the breaker for repair. A jacking device is then set up in the operating mechanism (Fig. 213) for manual closings and openings.

The bottom of each tank covered with boards and a ladder is placed on them for inside work.

Before dismantling the arc-control chambers, the breaker is closed and opened manually to check the operation of the tie rods, levers and the associated mechanisms. After this, the jumpers connecting the shunting resistors *24* (Fig. 208) and the arc-control chambers are removed and the shunting resistors are lifted off.

To obtain access to the moving contacts in the arc-control chambers for inspection, the screws *3* are undone and the shields *15* are taken off. Next the bolts *14* are unscrewed and the insulating rod *9*, lower cover, spring assembly *1*, contact jumpers, flexible connectors *2* and lower contact *16* are removed as one unit by turning it through nearly 90 degrees and pulling it out of the arc-control chamber.

Whether or not the arc-control chambers have to be taken further apart depends upon the condition of the contacts. If they are in good shape, the contacts may be washed and the inside of the bakelite sleeves cleaned with transformer oil without removing them from the arc-control chambers. If the contacts are pitted and show a heavy deposit of carbon, the sleeve and fixed contacts will have to be dismantled. For this purpose, the bolts *23* holding the retaining ring *21* against the contact bushing *22* are unscrewed leaving one bolt about which the ring and sleeve can be turned together and the sleeve can be taken out of the ring, exercising utmost care not to bend the bolt or break the ring. The sleeve should be taken out of the tank and into the repair shop for dismantling so as not to scratch the insulation. In the shop the sleeve should be put on a pad of soft material.

Next the bolts *6* are unscrewed and the cover *7* is taken off from the arc-control chamber. Now all parts of the chamber are thoroughly examined, cleaned and washed with transformer oil. The bakelised-paper parts are examined for cracks and lamination and the cermet arc-quenching plates for reliable soldering to the contact jumpers. Traces of pitting on the contact surfaces should be removed on a

grindwheel or with a coarse-cut file. The machined contact surfaces are checked for perpendicularity to the axis of the contact with a rule, square edge and caliper.

If the contacts have worn down by more than 2 mm, they should be replaced.

Where kirite (copper-tungsten cermet) plates have to be replaced, they should be brazed to the circuit breaker contacts with an oxy-acetylene torch and ПМЦ-36 copper-zinc brazing solder.

The scorched and blackened insulating parts within the chambers are cleaned and given three coats of No. 4C oil varnish, allowing each coat to dry at 15° to 20°C. At the same time the springs *1* are checked for resilience and flexible connectors *2* for reliable fastening.

The shunting resistors are checked in the same manner as when the circuit breaker is first installed (see the end of Sec. 32).

Before reassembly of the arc-control chambers, all the parts should be wiped with lint-free rags, or, better, blown off with compressed air.

After the arc-control chambers have been assembled, the contact jumpers mounted on the insulating rod are checked to see that they are free to move in the paper-laminate guide blocks and make contact with the fixed contacts.

If, during an overhaul, the jumpers on the insulating rod and the fixed contacts in the bakelised-paper sleeve were moved out of their factory-adjusted positions, it is necessary to check the contacts in the cylinder for simultaneous closure (Fig. 219) and proper follow-through before completing the assembly of the chambers. The contacts should meet simultaneously, accurate to within 1 mm.

МКП-110 oil circuit breakers manufactured before 1957 have arc-control chambers of inadequate arc-controlling capacity. Therefore, during the earliest possible overhaul the following improvements should be made in their construction. In addition to the two pressure-relief openings located near the fixed arcing contacts, a hole 25 mm in diameter should be drilled near the fixed contact and symmetrical to the existing hole. This hole should be drilled radially, its edges de-burred with a scraper, and its surface given a coat of БФ-4 varnish. Care must be taken that the tip of the drill will not separate the layers of bakelised paper on the reverse side.

The 5-mm laminate straps on the fixed contacts should be replaced by straps of the same size made from electrical-grade fibre. The new straps should be fitted so that they do not block the gas vents.

The moving contacts should be replaced with new contacts having an insulating coating. Instead of the paper-laminate arc-quenching grids, fibre grids should be installed. If fibre 35 mm thick is unavailable, the grids may be built up of two or three layers of thinner fibre. In the latter case the fibre layers are cemented together with

БФ-4 varnish, pulled together by textolite studs, and baked in an oven at a temperature up to 70°C for 6 to 8 hours.

During an overhaul, the insulated lift rods are checked for cracks, laminations, the strength of the joint between the rod and the end fittings, and for free movement in the guides. Defective rods should be replaced.

Concurrently, the lift rods and their guides should be checked to see that they have been properly suspended. Each lift rod should be plumbed, and the guide should be adjusted so that the radial clearance between the guide and rod is 1 to 1.5 mm. The manufacturer's instructions permit light contact between the lift rods and their guides. The guides are then fastened at their tops with bolts and split spring washers.

The contact rods should be cleaned of traces of fusion and carbon deposit. When pitted deeper than 2 mm, the rod tips should be replaced. At the same time the contact rods are checked for fixation in the cross-arm, and the stop screws are tested for tightness.

The terminal bushings on the circuit breaker are examined for cracks in the upper and lower porcelain shells and chipped spots on their surfaces. After this the porcelain is wiped with lint-free clean rags moistened with petrol.

The cemented joints between the porcelain shells and their flanges are also examined and given several coats of air-drying varnish. Where local crumbling of the cement is detected, it should be repatched in place and given three coats of natural boiled linseed oil or varnish, allowing each coat to dry fully. When a terminal bushing requires complete recementing, it must be sent to a repair shop.

The terminal bushings are also checked for reliable fixation to the breaker top plate. For this, the fixing bolts should be tightened, giving a quarter-turn at a time to the bolt across from the previous one. At the same time, it is necessary to see that the rubber gasket is good and properly placed.

The top of each bushing should be examined to see that the entry of the terminal rod is reliably sealed.

When a bushing has to be replaced, the arc-quenching assembly is first removed, the bolts clamping the bushing holder to the cast-iron current transformer casing are unscrewed, and the bushing is lifted off with a crane or some other hoisting facility in the same manner as when installing a modernised МКП-110 breaker. The new bushing is mounted much as it is during the initial installation of the circuit breaker.

As part of an overhaul, the pebbles filling the oil baffles are washed, the gas vents and valves cleaned, the relief valves checked for

their membranes, and the oil-level gauges and the oil-filling and oil-drain cocks on the circuit-breaker tanks are checked and cleaned.

The tank insulation is also checked and repaired, if necessary, and the nuts on the fastenings are tightened.

To prevent the ingress of moisture through the clamping bolt holes in the breaker top plate, the manufacturer's instructions recommend that during an overhaul the spring washers should be replaced by flat washers and tow packing coated with bakelite varnish.

73. Maintenance of Air-blast Circuit Breakers

In-service inspection and care. Air-blast circuit breakers, while in service, should be inspected daily and also after every closing or opening operation.

The main point to be watched in an inspection is the pressure in the air receivers, which should be between 16 and 21 atm gauge for nonreclosing types and 19 to 21 atm gauge for automatically reclosing types, as read from the pressure gauge in the control cabinet.

The porcelain of the supporting columns is checked for mechanical injury, dust, and defects where the porcelain is secured to the breaker truck.

By reference to the blow-off indicator, the ball of which should be near the red mark on the indicator body, it is determined whether the air is dry. It is impermissible to use a circuit breaker with a defective air-drying system. It is also necessary to see that the interrupter-chamber seals have not been blown out by the compressed air during the last operation of the breaker, that the exhaust hood flaps are fully shut, and, in winter, that there are no signs of icing — a condition entirely intolerable. Ice formation should also be watched for on the breaker as a whole, and on the fixed contact of the isolator in particular. Air leakage, if any, is detected by listening, oil leakage from the isolator dashpot by visual inspection.

The position of the isolator contact blades is checked next. In the closed position the tip of each male blade should be entirely between the parallel jaws of the fixed contact. In the open position the blade should make an angle of 73 degrees with the horizontal.

Temper colours can provide a check on whether the isolator contacts and the breaker terminal connections have been overheated.

Preventire maintenance repair. As a rule, preventive maintenance repair is carried out twice a year. This includes inspection and repair of the interrupter units, the isolator operating mechanism, blade and fixed contact, as well as the electrical equipment in the control cabinet. Concurrently, the entire breaker is thoroughly examined and its insulators wiped clean.

Preventive maintenance repair covers the following operations:

1. preparation for repair;

2. disconnection of the circuit breaker, preparation of the location around the circuit breaker, and admission of the repair crew to the circuit breaker;

3. a resistance test of the interrupter contacts (performed by special crew);

4. inspection and repair of the isolator mechanism and blade (without their dismantling);

5. inspection and repair of the isolator fixed contact (without dismantling);

6. inspection and repair of electrical components in the control cabinet and inspection of its other assemblies;

7. inspection and repair of air distribution cabinet components;

8. performance tests and checks (carried out by special crews).

In addition, the air receivers should be opened once a year and all bolted joints checked and tightened, if necessary, at the same time.

In conclusion, the breaker is reconnected to the feed mains and the air pressure is raised in its receivers.

The circuit breaker is then closed and opened locally. If the trial closing and opening operations are satisfactory, the circuit breaker is again operated by remote control and prepared for putting into service.

Overhaul. The overhaul period for this type of circuit breaker is two years. In an overhaul, all the parts and assemblies of the circuit breaker are repaired, including the arc interrupter unit, the isolator, its mechanism, the support column, the isolator contact and its insulator stack, the electrical and pneumatic components in the control cabinet, and the air receivers. Worn or unsatisfactory parts are replaced.

The air distributor cabinet is repaired concurrently with the circuit breaker.

A typical overhaul includes the following:

1. preparation for repair;

2. disconnection of the circuit breaker, release of the air from the air receivers, and admission of the repair crews to the location;

3. demounting and repair of the arc interrupter units;

4. repair of the isolator mechanism and blade;

5. repair of the isolator fixed contact;

6. repair of control cabinet components, including the pneumatic devices;

7. repair of the air receivers;

8. assembly of breaker poles;

9. repair of air distributor cabinet components;

10. adjustment and testing of each breaker pole.

After the overhaul, the circuit breaker is formally accepted for service, reconnected to the line, and put into operation.

The main support insulator containing the air lines should also be given an inspection during an overhaul. It should be taken apart and cleaned at least every four years and as the need may arise.

74. Possible Troubles in the Main Types of Circuit Breakers and Their Remedy

If a circuit breaker fails to close, the first thing to check is whether the fuse in the closing solenoid circuit has blown. In some cases this is indicated by the respective signal lamp going out, in which case the blown fuse should be replaced.

A circuit breaker may also fail to close because of reduced control voltage at the operating mechanism, in which case the voltage should be raised to its normal value.

A failure of the circuit breaker to close may further be due to a mechanical trouble in the pilot contactor. To check the latter, the contactor is de-energised and closed by hand to see if there is any binding in its mechanical system.

A likely cause may be a break in the contactor coil, which should then be replaced. If the main contacts are found to be heavily fused, they should be filed or replaced.

Still another cause of a circuit breaker's failure to close may be a break in the closing circuit wiring. This can be ascertained by connecting a trouble lamp across the closing contacts of the control switch. If a break is found to exist, the circuit should be checked with a megger and the continuity of the circuit restored.

In some cases the closing solenoid fails to develop full pull at its plunger because of a break in one of the parallel-connected coils. The defective coil should be either repaired or replaced.

The contactor should also be checked to see that its spring is not too tightly compressed; if so, it should be partially released.

A circuit breaker may fail to close because the interlock contacts of the trip-coil core or in the closing-coil circuit are faulty. In such cases they should be cleaned and readjusted for proper operation.

It is not improbable that the trouble is due to the core of the closing solenoid sticking in the coil. This requires washing of the core in kerosene and some lubrication with petroleum jelly or a special grease.

It may occur that a circuit breaker fails to open when it is in service. This may be due to blowing of the fuse in the trip circuit, low voltage or a break in the trip circuit and the core sticking in the trip-coil. The remedies for these faults are the same as for failures of the circuit breaker to close.

CHAPTER 13

POWER TRANSFORMER OPERATION AND MAINTENANCE

Transformers are among the simplest items of electrical equipment in construction, are reliable in service and convenient to operate and maintain. Transformer maintenance mainly includes periodic supervision of its operation, timely inspection, preventive maintenance and overhauls, and control of its temperature and load. A special feature of transformer operation and maintenance is constant watch on the oil, which serves not only as insulation, but also as the cooling medium.

Early detection of any slight changes in the physical and chemical properties of the oil makes it possible to take timely measures to eliminate troubles in the transformer and preclude grave breakdowns. This calls for knowledge of oil behaviour in transformers.

75. Transformer Oil Maintenance

The properties of oil important to transformer operation are electric strength (breakdown voltage), flash point, viscosity, and acidity, and also the moisture and mechanical impurities content. Any change in the properties is a sign of oil deterioration due to some trouble in the transformer which must be immediately remedied.

Lowered flash point. The most common cause is known as cracking (decomposition) of oil due to local overheating ("burning" of the core). The overheating may be due to several internal faults, such as breakdown of the insulation between the core steel laminations, poor contact in the tap changer switch, windings or terminals under the cover, and a partial turn-to-turn short circuit in a winding which provides a closed circuit for a heavy current.

Mechanical impurities hinder normal cooling of the transformer, foul the windings and may also lead to a voltage flash-over on the insulation as they can form a leakage path.

Increased viscosity of the oil impairs transformer cooling because it decreases the rate of oil circulation and results in a higher temperature rise of the oil and the unit as a whole.

Reduced electric strength may lead to a winding-insulation breakdown and failure of the transformer. Reduced electric strength is a sign that the oil contains moisture and organic acids which have appeared as a result of oil deterioration.

Increased acidity leads to deterioration of the transformer-winding insulation.

To avoid the adverse conditions listed above, relevant standards set the respective figures for the properties of oil, both fresh and used (see Table 33), as well as the intervals of time at which samples should be taken from transformers and other oil-filled apparatus. A knowledge of these standards is essential if such equipment is to be maintained efficiently.

Table 33

Properties of Transformer Insulating Oil

Oil property	Fresh oil	Oil in service
Electric strength (min), for ratings up to 10 kv	35 kv	20 kv
Same, for ratings 11 to 35 kv	35 kv	25 kv
Same, for ratings 35 to 220 kv	40 kv	35 kv
Same, for ratings 200 to 500 kv	50 kv	45 kv
Moisture, mechanical impurities, semi-colloidal carbon	None	None
Flash point, °C (min)	135° C	max 5°C lower
Acidity value (max)	0.05 mg KOH/kg	0.4 mg KOH/kg
Viscosity, Engler units (max)		
(a) at 20° C	4.2	4.2
(b) at 50° C	1.8	1.8

Transformer oil should be subjected to laboratory tests at the following intervals of time:

(a) oil from transformers and apparatus rated for up to 10 kv inclusive: a proximate analysis at least every three years; oil from transformers and apparatus rated for 10 to 35 kv inclusive: a breakdown test once a year and a proximate analysis at least every three years;

(b) oil from transformers and apparatus for higher than 35 kv: a breakdown test and a proximate analysis once a year;

(c) oil from sealed transformers: a breakdown test every two years;

(d) oil from oil-filled bushings: a proximate analysis once a year;

(e) oil from a transformer or apparatus after an overhaul: a proximate analysis.

After an oil circuit breaker has interrupted a short circuit, a sample of the oil should be sent to the laboratory for a semi-colloidal carbon content test.

An electric strength test includes a breakdown test and a determination of semi-colloidal carbon and mechanical impurities.

A proximity analysis includes determination of flash point, electric strength, acidity value, semi-colloidal carbon, mechanical impurities, and moisture.

Deterioration of transformer oil is brought about by overheating. The service life of the oil in a transformer is halved if its temperature is 10°C above normal. When a transformer is in service, the maximum temperature rise of the top layers of the oil should not exceed 60°C above an ambient temperature of +35°C. However, if oil is to have a longer service life, transformers should be operated so that top-oil temperature does not exceed 85°C. Large transformers have devices which set off an alarm when this temperature is exceeded.

76. Transformer Overloads

In the course of a day, and also depending upon the season of the year, the load on a transformer will not remain constant, which fact brings about variations in the temperature at which the transformer is operating.

A winding temperature rise of 70°C to some value below it reduces the rate of deterioration of the winding insulation and extends transformer service life. Therefore, the overloads should be limited to values which will not cause temperatures in excess of the one given above, so that transformer service life will be not shorter than 20 to 25 years. Transformer overloads may be continuous and emergency.

Table 34 summarises continuous-load limits for all types of power transformers at different load factors.

The rule for determining the permissible continuous loading of transformers is as follows. A transformer may be overloaded continuously 1 per cent above its rating in winter for each per cent that its maximum daily average load is below its rated kva in summer, but by not more than 15 per cent. It is possible to observe both of the above limits, but then the overload must not exceed 30%.

All conventional types of self-cooled oil-immersed transformers may be allowed to carry emergency overloads for the period of time needed to bring in a stand-by unit. This emergency overload is independent of the previous load, ambient temperature and the

Table 34

Limits of Continuous Transformer Overloads

Load factor (determined from daily load schedule)	Per cent limits and duration of overloads					
	2 hours	4 hours	6 hours	8 hours	10 hours	12 hours
0.5	28	24	20	16	12	7
0.6	23	20	17	14	10	6
0.7	17.5	15	12.5	10	7.5	5
0.75	14	12	10	8	6	4
0.8	11.5	10	8.5	7	5.5	3
0.85	8	7	6	4.5	3	2
0.9	4	3	2	—	—	—

transformer location. The limits and durations of emergency overloads are:

Load in per cent of rated kva	130	160	175	200
Permissible duration, min	120	45	20	10

For dry-type transformers the permissible limits and durations of overloads are:

Load in per cent of rated kva	110	120	130	140	150	160
Permissible duration, min	75	60	48	35	20	5

77. Transformer Inspection

Regular inspection is vital to the efficient operation and maintenance of transformers.

Main and station transformers should be inspected daily without disconnecting them from the line, and all other transformers in attended installations, every five days. In unattended installations the transformers should be inspected at least every month, and at transformer substations, at least every six months.

To prevent accidents, attending personnel should inspect a power transformer while standing on the threshold of the transformer cell or bay outside the guard barrier. An inspector may go beyond the

guard only if the lower flanges of the bushings on the transformer tank cover are at least 2 metres above floor level and the unguarded live parts above the passageway are at least 2.75 metres above floor level for a working voltage of 35 kv, and 3.5 metres for a voltage of 110 kv.

Off-schedule transformer inspections are made when the ambient temperature has changed sharply, each time a transformer has been disconnected by its protective devices, or a warning signal has come from the Buchholz relay.

The points to be watched during an inspection of power transformers are:

(a) the approaches and passages to the substation should not be obstructed;

(b) the fences, guards, doors, window and ventilating openings, and the structure as a whole should be intact, and the roof should not be leaky;

(c) the thermometers and pressure gauges should read accurately;

(d) the transformer tanks should be intact, no oil should leak at the tank cover joints, flanges and drain valves, the oil level in the conservator should be sufficient for the prevailing temperature, and the oil-filled bushings should be filled with oil;

(e) the oil-cooler and oil-sump should be in working condition; the bushings and lightning arresters should be free from breaks; there should be no dust or dirt on them, the tank and other surfaces;

(f) the busbars and cables should be free from damage and any signs of heating at their joints;

(g) the lighting facilities, alarm system and the spark gap fuses should be in working condition;

(h) the earthing system and the fire fighting equipment should be in good order;

(i) the conservator should be free to communicate with the transformer tank, which condition can be checked by draining some oil through the pet cock and watching the oil level in the gauge glass drop;

(j) whether or not much moisture and sludge has accumulated at the bottom of the conservator;

(k) the continuous oil purifiers and the thermosyphon filters should operate normally, and the breathers should be charged with fresh silicagel.

Any troubles or defects discovered during an inspection should be remedied at the earliest possible occasion; in cases of emergency or an accident, the unit must be immediately disconnected from the line.

Power transformers should be disconnected from the line in the following cases:

(a) loud and undulating humming and crackling can be heard in the transformer;

(b) the temperature rise of the transformer is abnormal and continuously increasing at rated load and cooling conditions;

(c) oil has been expelled from the conservator, or the safety membrane in the gas vent pipe has burst;

(d) the oil has been leaking and its level has dropped in the oil gauge;

(e) the oil has undergone a change in colour (several steps on the colour scale);

(f) the porcelain on the bushings is cracked or chipped, creeping charges have appeared on the surface, or traces of flash-over have been found;

(g) the oil contains semi-colloidal carbon, moisture, and mechanical impurities, or it has increased acidity, lowered breakdown voltage, and a flash point which is more than 5°C below that of the previous test; the insulation resistance has decreased by more than 50% of its original value, or in relation to the value stated by the manufacturer.

78. Maintenance of the Buchholz Relay

Any fault which occurs inside a transformer is generally accompanied by the evolution of gas. Therefore, each transformer is equipped with a gas-sensing Buchholz relay. It has alarm and tripping contacts so that audible warning can be given and a major breakdown can be averted. If the Buchholz relay is to operate efficiently, the transformer should be set so that its tank cover has a rising slope of at least 1 to 1.5 per cent in the direction of the relay. The oil piping from the transformer to the conservator should have a rising slope of not less than 2 to 4 per cent. Audible warning will be given when air finds its way into the transformer, when the oil level slowly falls due to low temperature or oil leakage, and also when minor faults accompanied by the evolution of small amounts of gas occur.

False alarm may be sounded when a through short circuit causes the oil to rush through the Buchholz relay and also when the small wiring at the relay is faulty due to the fact that the insulation is often damaged by the oil. To avoid such cases, the wiring to the relay should have oil-resistant insulation.

An examination of the gas from the Buchholz relay can give attending personnel an idea of the nature of the fault in the transformer and the cause of operation of the relay.

If the gas in the relay is without colour and odour, and will not burn, air is present in the transformer. If the gas burns, an internal

fault has occurred in the transformer, and the latter must be immediately switched out for repair.

The nature of the fault in a transformer can also be identified by the colour of the gas in the relay (Table 35).

Table 35

Transformer Faults as Identified by Colour of Gas

Colour of gas	Source of fault
White-grey	Paper or pressboard
Yellow	Wooden parts
Black	Oil

To ignite the gas for a test, the flame should be brought from aside and above the test cock. To avoid an explosion, the flame should never be brought to the opened conservator or access opening in the transformer.

If, when the Buchholz relay has given an alarm, there is a stand-by transformer available, the load should be transferred to the latter. The faulty transformer should be then examined to determine the cause of operation of the Buchholz relay.

When noninflammable gases are regularly evolved from the oil in the transformer, the oil should be tested for its methane and hydrogen content. If their content gradually increases, the transformer should be switched out for repair, since this is an indication that the oil is being cracked by arcing. If the oil level drops due to decreasing ambient temperature, some more oil should be added. Since fresh oil gives off bubbles of air, it is usual to defer connecting the relay tripping contacts for some time in order to prevent false tripping. If the Buchholz relay has operated due to a cause other than accumulation of air in the transformer, the oil should be tested for flash point.

When the Buchholz relay has disconnected the transformer from the line due to an internal fault, the transformer may only be switched back after the windings and core assembly have been inspected and tested.

79. Transformer Repair

Routine, preventive maintenance work on power transformers (without removing the windings and core) with the transformer disconnected from the line, is carried out in accordance with the

conditions of operation obtaining and in conformity with local regulations, but at least every year.

Overhauls of power transformers (with the windings and core assembly lifted out) are carried out after 5 years of service. Subsequent overhauls are scheduled on the strength of inspections and tests.

Routine preventive maintenance consists in cleaning the bushings and cover; inspecting all contact joints, the conservator, gas vent pipe, testing the Buchholz relay, etc., which usually takes 6 to 8 hours to complete.

Overhauls are performed with the windings and core assembly lifted out and also include an internal inspection of the transformer, i. e., of the magnetic circuit, all clamping bolts and other bolted joints, windings, contact joints and insulation; cleaning of the tank and conservator, replacement of all gaskets, and all standard tests. The time required for an overhaul of a transformer is one to ten days, depending upon its size.

CHAPTER 14

OPERATION AND MAINTENANCE OF ALTERNATORS

80. General

The fundamental unit of an electric power station is the synchronous generator or alternator, the machine which generates the alternating current.

With a steam turbine as its prime mover, it is called a turbogenerator or turboalternator (Figs 315, 316, 317). Water-wheel generator or water-wheel alternator is the name given to an alternator driven by a water turbine.

The duties of electrical attendant personnel in supervision of a running generator. Constant watch on and care of a running generator as a whole and its various parts is entrusted to the turbine-house operator.

He should listen to the generator, check the temperature of its bearings and the cooling air, keep watch on the brushgear, and keep the unit clean. He should immediately inform electrical maintenance personnel of any abnormal or faulty operation detected in the generator.

The electrical attendant personnel also keep continuous watch on operation of the generator (or generators), namely:

1. Keep continuous records of stator voltage and current, exciter voltage and current, active and reactive power, loads, kwh output, and the temperature of the windings, stator core, and cooling medium. A regular check should also be kept on the symmetry of the stator currents of each generator by means of the ammeters connected in each phase or one ammeter and a selector switch. A general view of the generator controls on a main control board is shown in Fig. 318.

2. Test the insulation resistance of the excitation circuit with a voltmeter once a shift by measuring the voltages V_1 and V_2 between each rotor collector ring and the generator shaft, and the voltage

E between the collector rings. The insulation resistance is calculated by the equation:

$$r_{ins} = r_v \left(\frac{E}{V_1 + V_2} - 1 \right) \times 10^{-6} \text{ megohms},$$

where: r_v — internal resistance of the voltmeter (anywhere between 50,000 and 100,000 ohms).

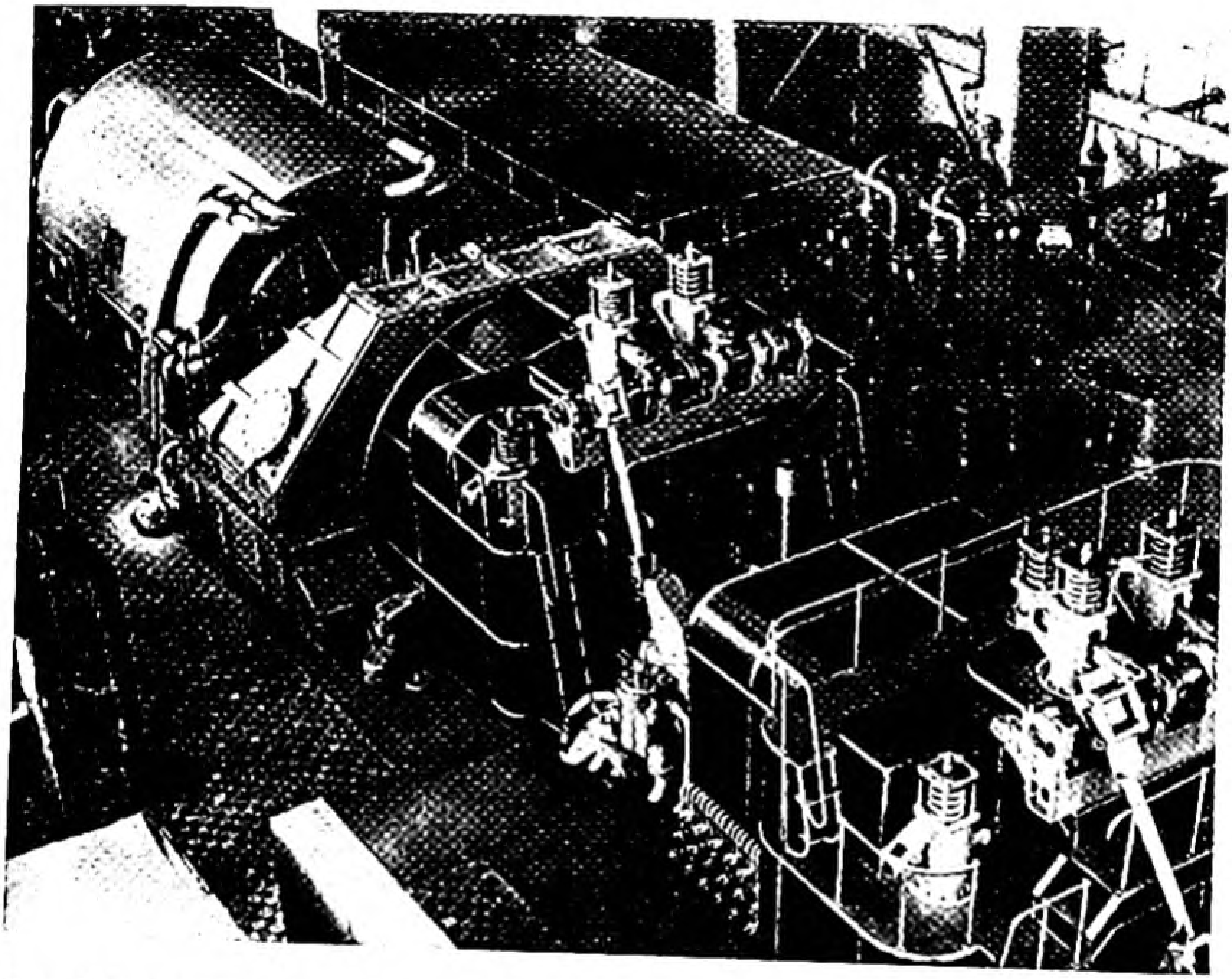


Fig. 315 General view of a turbine-generator set consisting of a TB-60-2 turbo-generator and a ВПТ-50-3 steam turbine

The results are entered in a special log-book. For a running machine the insulation resistance should be not less than 0.5 megohm. If it is, measures should be taken to restore insulation resistance, in particular by blowing carbon dust off the brushgear with compressed air, cleaning the brushgear, etc. If the insulation resistance cannot be restored with the unit running this should be done during a repair period.

3. Keep constant watch on the condition of the stator winding insulation.

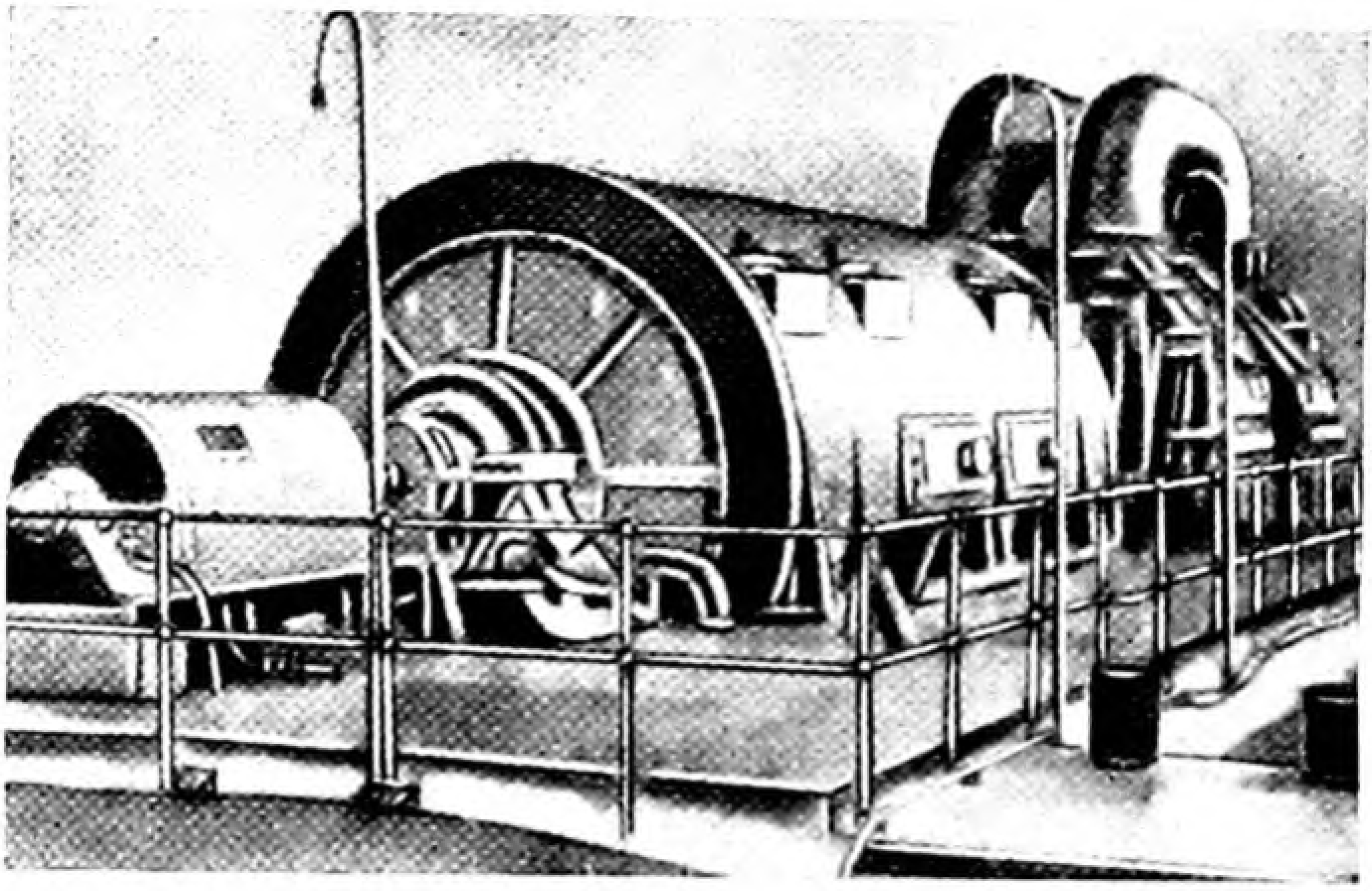


Fig. 316. General view of a 150 MW hydrogen-cooled turbogenerator

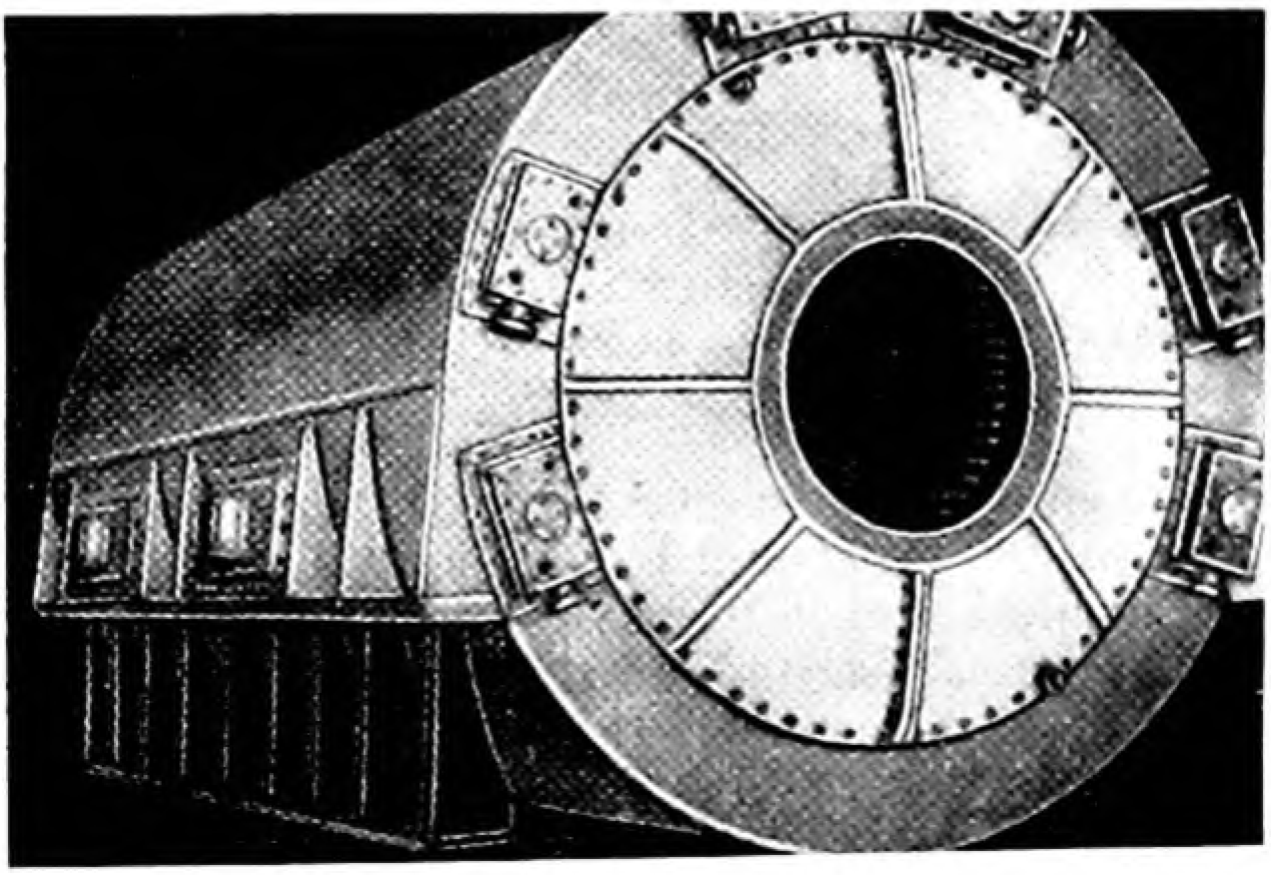


Fig. 317. General view of the stator of a 100 MW, hydrogen-cooled turbogenerator

The insulation resistance of the stator winding should be tested during shutdowns with a 1,000-2,500-volt megohmmeter. No particular value is specified by standards. A good plan, however, will be to compare the results of a test with those of the previous one. When the insulation resistance sharply decreases (3 to 5 times), the cause should be identified and measures taken to eliminate it.

4. Examine, every 7 to 10 days, the insulating pads under the turbogenerator bearing pedestals. In a running generator, an alternat-

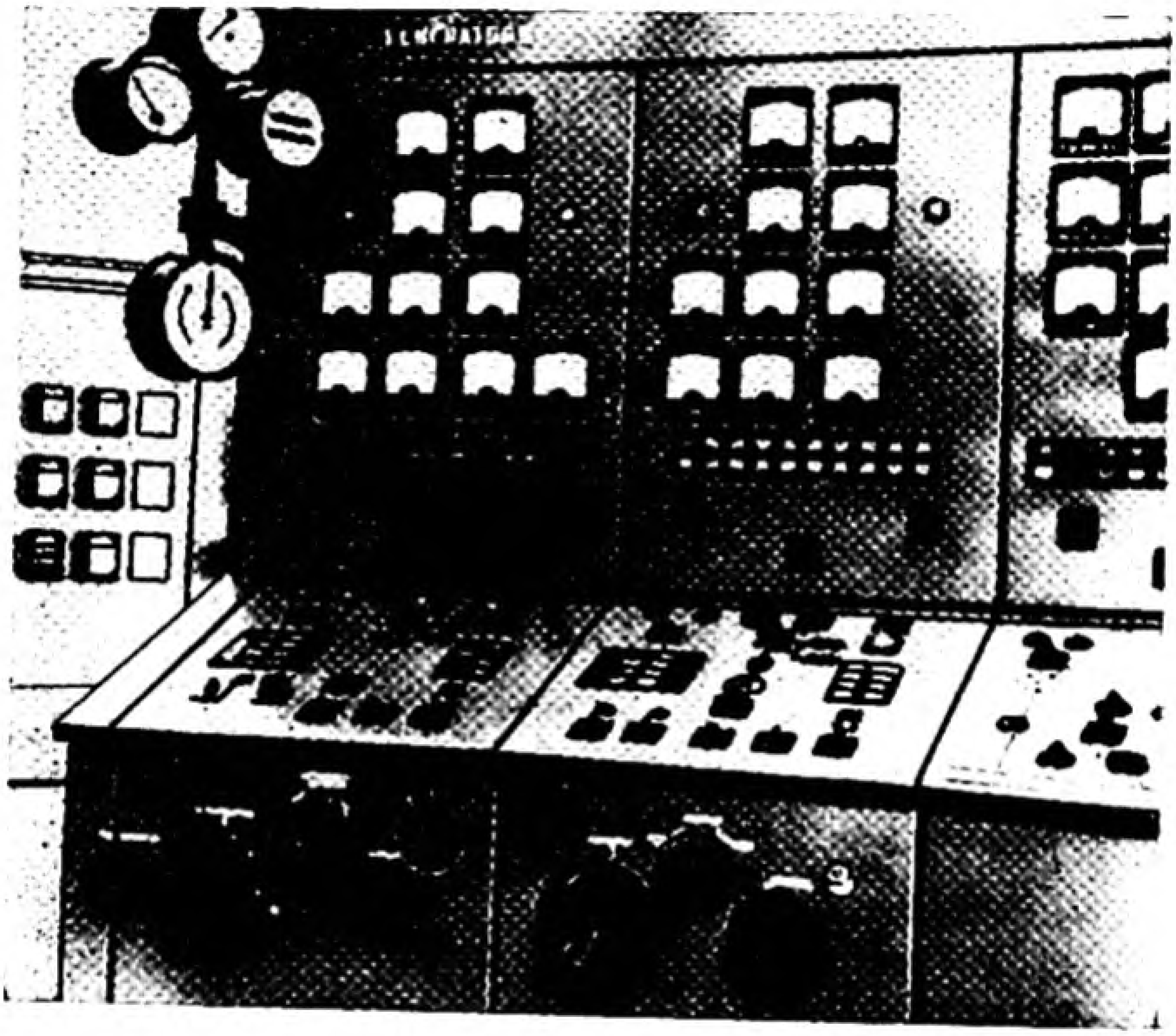


Fig 318 Generator controls on a main control board

ing emf is induced along the rotor shaft, giving rise to currents circulating through the bearings of the set (Fig. 319). These currents may damage the shaft journals and bearing-liners. To prevent this, the turbogenerator bearing at the exciter end and the bearings of the turbogenerator exciter are insulated from their bed-plates by insulating pads. In addition, two adjoining flanges on each oil line are insulated from one another.

The resistance of the bearing insulation, with turbogenerator running, is tested as shown diagrammatically in Fig. 320. When the insulation is good, the voltmeters V_1 and V_2 will give identical readings. A difference in readings greater than 10 per cent indicates that the

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insulation has deteriorated, and the voltmeter V_2 will read less than the voltmeter V_1.

5. Assist in maintaining the station's daily schedule of active load, and voltage or reactive power.

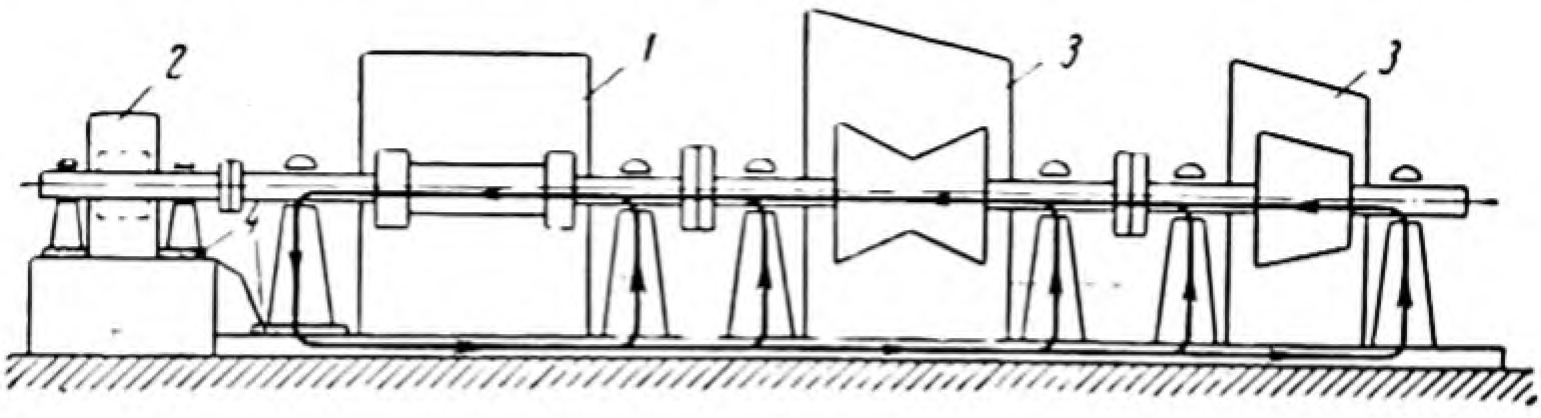


Fig. 319. Paths of bearing currents in a turbine-generator set
1—generator; 2—exciter; 3—turbine; 4—insulating pads

The daily active and reactive load schedule determines how much power a station should deliver or distribute every hour. The schedule comes from the chief operator of the system and should be followed without fail. Guided by this schedule, the station's engineer divides the load between the generating units, and the attending personnel maintains it constant.

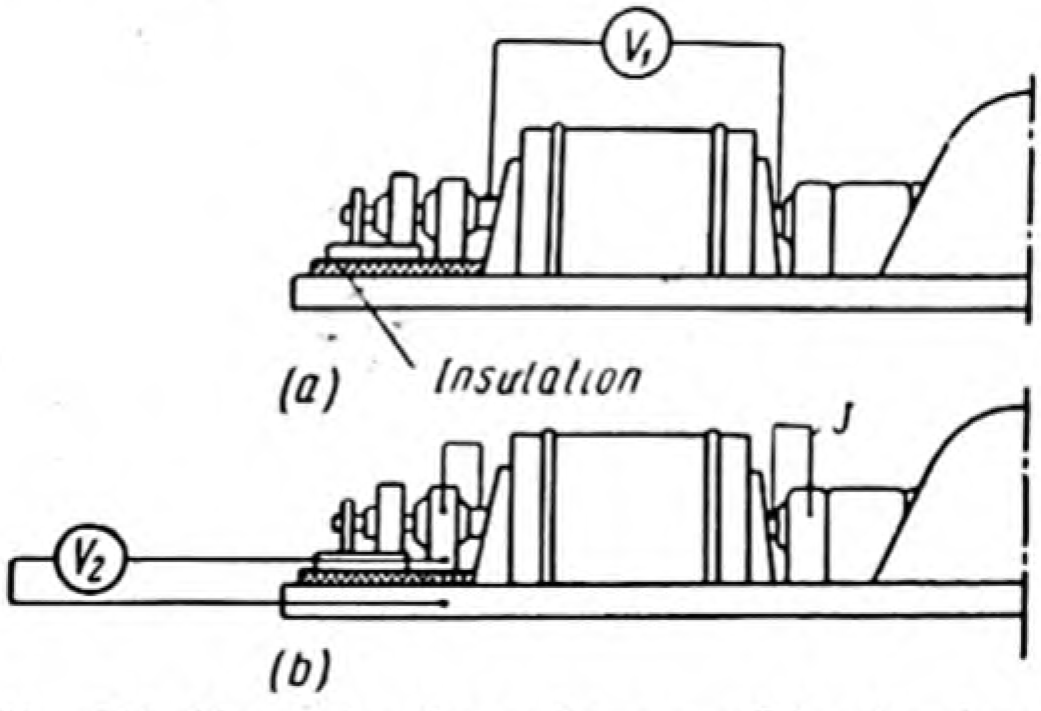


Fig. 320. Measuring for resistance of bearing insulation during operation of turbogenerator:
a—reading of voltage across the ends of the shaft; b—reading of voltage between the bearing and the bedplate at the underbearing insulation; (J—jumper used to shunt lubricating-oil film).

The necessary active or kw load is maintained by controlling the rate of steam flow into the steam turbine or the rate of water flow into the water turbine and watching the wattmeters.

The prescribed voltage or reactive load is maintained by measuring the excitation current of one or several generators. A larger

exciting current corresponds to a larger stator current and a greater reactive load on the generator, and a higher voltage at its terminals. Conversely, a smaller excitation current corresponds to a smaller stator current, a smaller reactive load on the generator, and a lower voltage at its terminals.

At present the voltage of generators rated at 3,000 kw and higher is regulated automatically by voltage regulators which are adjusted so that when the voltage drops due to an emergency in the system, it is raised by varying the maximum field current. In addition, the excitation circuit incorporates a field rheostat for manual voltage adjustments.

Though the operators can obtain a complete picture of how the various pieces of station plant function from the respective instruments, they should make a round of the generator once a shift in order to:

(a) listen to the running generator for any deviation from normal operation;

(b) check the temperature rise of the bearings, stator and exciter;

(c) inspect the brushgear of the generator and exciter; sparking, if any is noticed, is eliminated by adjusting the spring pressure, cleaning the brushes, collector rings and exciter commutator;

(d) detect any heating in current-carrying parts with the aid of a temperature indicator and by changes in colour;

(e) carefully inspect the entire relay equipment, the alarm circuits for any failure to operate properly. This same procedure of inspections should be followed after each external short circuit.

81. Abnormal Operating Conditions and Troubles of Generators

Overloads. All overloads are harmful to the stator and rotor insulation because the temperature rise causes the copper to elongate, thus deforming the end windings. This, in turn, may lead to turn-to-turn shorts in the windings. Because of this, generators should not be loaded for considerable periods of time with currents greater than is permissible at a given temperature of the cooling air or gas.

Short-time current overloads of the stator and rotor, irrespective of the temperature of the cooling air or gas, is only permissible in cases of emergency in the system. Their limits and duration are given below:

Overcurrent ratio . . .	1.1	1.15	1.2	1.25	1.3	1.4	1.5	2.0
Duration, minutes . . .	60	15	6	5	4	3	2	1

Earth faults. Generator operation with an earth fault existing in the generator-voltage circuit may be tolerated for not more than two hours. When an earth fault appears in the rotor winding of a generator, the operator should identify and locate the fault. In the case of a sustained and solid earth fault, the protection of the excitation system against double earth faults should be switched in.

A generator having an earth fault in its rotor winding should be taken off the line for repair at the earliest opportunity.

Unbalanced loads. Turbogenerators are designed to carry full load continuously with the phases loaded equally to within 10 per cent of the rated stator current. Water-wheel generators are designed

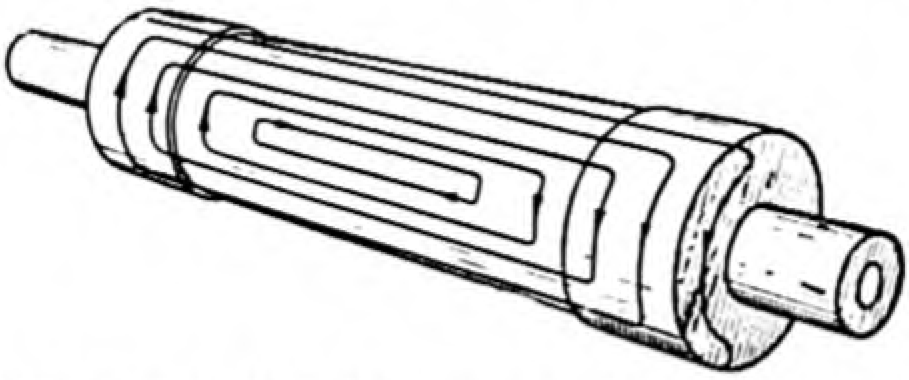


Fig. 321. Paths of currents induced in the rotor of a turbogenerator by the negative-sequence magnetic field

to do the same with the phases loaded equally to within 20 per cent. In both cases the current in any one phase should not exceed its rated value. Whenever load unbalance grows excessive, measures should be taken to reduce it. In the case of failure to do so within 2 minutes, the load should be disconnected, and the generator switched off the line. This should be done because under unbalanced load the revolving magnetic field of the stator winding fluctuates greatly in magnitude and causes negative-sequence fluxes to appear. As a result, double-frequency currents are induced in the field winding and the rotor core (Fig. 321). They give rise to additional losses both in the metallic parts of the rotor and in the field winding proper and result in dangerous hot spots.

Asynchronous running condition. Operation in the asynchronous running condition which occurs when the excitation disappears during operation may be tolerated for 30 minutes. The load which the generator may be allowed to carry in such cases is determined by test.

Disconnection by relays. If the generator has been switched off the line by its relays because of an internal fault, the insulation resistance of the stator and rotor windings must be tested, the generator inspected, and its associated equipment and cables checked. If the generator has been switched out by an overcurrent relay due to

a short circuit in the system or on the station buses, it may be put into operation.

Appearance of the "Machine in Danger" signal. Should an emergency occur in the generator or the turbine (fire, flames, smoke, heavy vibration, etc.), calling for immediate disconnection of the generator, the set operator should strike the emergency automatic trip of the turbine and relay the "Machine in Danger" signal to the control board at once. The control board engineer should immediately make sure to remove its kw load, disconnect the machine from the line, and switch off the excitation current.

Sparking. All measures should be taken to eliminate heavy sparking on the exciter commutator or the generator collector rings. If necessary, the excitation current should be decreased, or the kw and reactive load lowered to a point where sparking ceases. If, again, this fails to stop the sparking, it is necessary to change over to a stand-by source of excitation current.

A generator in which a turn-to-turn short circuit has developed in the rotor winding should be immediately taken off the line.

Motor action of a generator does not present a danger to it for any interval of time, unless the associated turbine imposes any limitations.

82. Generator Preventive Maintenance

Generator preventive maintenance includes:

(1) Insulation resistance tests on the stator winding with a 1,000-2,500-v megohmmeter and with a 500-v megohmmeter on the rotor winding and all the excitation circuits.

(2) Measurement of d-c resistance of all the windings; a comparison with the readings obtained in the previous tests should show a difference of not more than 2 per cent.

(3) Insulation tests with the test voltage applied for 1 min between each phase and the frame, and the other two phases, with the latter earthed. The proof a-c voltage should be 1.5 to 1.7 times the rated line voltage. In generators with extended overhaul periods the stator-winding insulation should be tested with a proof voltage 1.7 times the rated line voltage.

(4) Testing of stator-winding insulation with a rectified voltage and concurrent measurement of leakage current. The test voltage should be 2.2 to 2.5 times the rated line voltage.

(5) Measuring of d-c resistance of the field-discharge resistor. The resistance should not differ by more than 10 per cent from the value specified in the Certificate.

(6) Testing of field-discharge resistor insulation with a proof voltage of 2 kv at commercial frequency for one minute.

(7) Testing of exciter armature-winding insulation relative to the frame and the wire banding with 1,000 volts a.c. for one minute.

(8) Resistance tests of generator bearing insulation to bed-plate with the oil lines joined. The insulation resistance should be not less than 1 megohm.

(9) Measurement of vibration. The vibration of bearings in synchronous generators and synchronous condensers should not exceed 0.18 mm at 62.5 to 187.5 rpm (rated); 0.12 mm at 214 to 375 rpm (rated); 0.10 mm at 500 to 1,000 rpm (rated); 0.07 mm at 1,500 rpm (rated); and 0.05 mm at 3,000 rpm (rated).

(10) Measurement of air gaps between stator and rotor. Under the Soviet Code, the air gaps across the diameter shall not differ by more than 2 per cent of the average value in water-wheel generators, and by more than 10 per cent of the average in turbogenerators and synchronous condensers.

(11) Plotting of a three-phase short-circuit characteristic. In the case of synchronous condensers this is obligatory only when they have a starting motor. The difference between the short-circuit characteristic thus obtained and that given by the manufacturer should be within the limits of instrumental accuracy.

(12) Testing of the bearing insulation relative to the bed-plate when the set is in operation. The voltage across the rotor shaft should equal the voltage between the bearing and the bed-plate, with the oil films of the bearings shorted.

(13) Testing of the generator synchronising circuits with synchronising voltage in cases when work has been done on them.

83. Generator Repair

All generators are regularly subjected to preventive-maintenance repairs and overhauls.

Preventive-maintenance repair includes:

(a) inspection and cleaning of the stator-winding end coils and generator leads;

(b) inspection and cleaning of the gas coolers, chambers and filters of the cooling system;

(c) inspection and cleaning of the exciter and the apparatus in the excitation circuits;

(d) inspection and cleaning of the associated switchgear.

A typical overhaul of a generator covers:

(a) the stator and rotor;

(b) the exciter;

(c) the excitation system;

(d) the shaft and thrust bearings;

(e) the gas coolers and cooling-system filters;

(f) the associated switchgear and auxiliary equipment.

Turbogenerators are overhauled after one year's service and thereafter at one to two years' intervals. Water-wheel-type generators have an overhaul period of two years. In the U.S.S.R., a district power authority has the right to extend this period to three years or more if the turbogenerator in question can be expected to operate without trouble.

The rotor of a turbogenerator is pulled out of the stator for inspection and repair after one year's service and whenever necessary afterwards, but at least every five years.

The rotor of a hydrogenerator is pulled out as the need may arise.

Drying-out of generators. After an overhaul, generators are put into operation without drying out. Newly installed generators may have to be dried out, depending on how moist their insulation is. The need for drying out is determined by special instructions. Generators may be dried out either prior to or during installation by one of the following methods:

(1) by heating the stator core with a magnetic field set up by a special exciting winding or by the rotor shaft;

(2) by heating the winding with direct current or hot-air blowers.

Both methods are employed when the generator is at a standstill.

Generators may also be dried out under load.

A generator is considered dried out when, at a steady temperature, insulation resistance and the $\frac{R_{60}}{R_{15}}$ ratio remain constant for three to five hours after an initial rise.

The rotor winding can be dried out:

(1) with direct current from an independent source;

(2) using hot-air blowers;

(3) concurrently with the stator, the rotor being inserted.

A rotor winding is considered dried out when its insulation resistance, after an increase, remains constant at not less than 0.5 megohms for three hours.

CHAPTER 15

MAINTENANCE OF OVERHEAD LINES

84. General

In the Soviet Union every power system has, as a rule, a ramified network of overhead lines which cover a large area. For convenience in control, operation and maintenance, the entire network is divided into districts, each including a number of substations and lines. Each such district is managed by a district office which has its own staff of operatives and maintenance men, workshops, transport facilities, etc.

The lines in each district are, in turn, subdivided into line sections for which patrol posts and line-service stations are responsible.

A patrol post is the primary link in the line-maintenance set-up. Such posts are staffed by two patrolmen residing at their post, who make periodic inspections of the lines in their subdistrict.

The line-service stations carry out routine maintenance work on the line sections. These stations employ several repair crews, each consisting of 4 to 5 linesmen, and have their own trucks, materials storehouse, and a repair shop. A line-service station is headed by a senior linesman.

The patrol posts and line-service stations within a district have telephone communication with one another and with their district office.

The duties of overhead line servicing personnel are:

(1) To maintain periodic inspection over the lines and to detect any faults which may lead to line outages.

(2) To perform the necessary repairs.

85. Inspection of Overhead Lines

Regular inspections (patrolling). Regular inspections over line sections are maintained by patrolmen.

The frequency of inspection depends on the country and the importance of the lines and is usually fixed by the chief engineer of a

given system. For the lines of industrial enterprises the frequency of inspection is fixed by their chief power engineers. In both cases, the interval should be at least every 3 months.

The main points to be watched by patrols are:

(a) Metal supports: tilted supports; deformed cross-arms and earth-wire supports; settled or bulging soil around support foundations; yielding of foundations, cracks or breaks in them above the ground line; missing nuts on the anchor bolts; rust and cracks (especially at joints and gussets); cracked welded joints and poor riveted and bolted joints.

(b) Wood-pole supports: tilted supports; misaligned support parts (cross-arms, etc.); earth poorly banked up around support poles; missing bolts and nuts; short thread on bolts; broken or loosened wire binders; missing keys and wedges; rotted, burned or split support poles.

(c) Conductors and earth-wires: foreign objects on conductors or earth-wires; excessive tension or sag; improper clearances; conductor corrosion, vibration, ice formation.

(d) Line accessories and joints: defective clamps, sleeves and connectors; cracks in clamps and similar parts; missing bolts, washers, or cotter pins; loosened nuts; signs of overheating on clamps or connectors; conductors slipping in their clamps; loose earth-wire; faulty cross loop at anchor supports (loop too near to tower part or bent); and loosened fixation of a conductor to an insulator.

(e) Insulators: broken porcelain, burned and fused spots on the glaze, traces of fusion and burning on the insulator and fittings; dirty insulators; deflected suspension strings; missing locks or cotter pins in suspension strings; spindles slipping out of insulator caps; bent pins and spindles; rusty fittings; noticeable corona.

(f) Earthing equipment: damaged or broken earth-wires at the ground level, missing conductor fixing staples on supports, and missing clamps at the tops.

(g) Lightning arresters: burned or damaged arcing horns and rings; defective indicators; fused electrodes in the external spark gaps, and wrong gap settings.

In addition, patrolmen should have to report on stacks of hay, peat or timber piled on the wayleave and on trees which have become a danger to the line and must be felled or trimmed.

Patrolling is necessary when trees and shrubs are being planted, earth moved, levelled, or blasted, cable and pipe lines laid, electric power and telephone lines erected, or unloading areas cleared within and near the wayleave.

The roads, road bridges and footpath bridges on the line route should also be inspected to insure their availability in times of need.

All faults and abnormalities detected by the patrolman should be entered in a Patrol Report tear-off notebook. The form of this Patrol Report is given below.

District No. ______________________________

Patrol Report

(Tear off original and send to district office. Leave duplicate in notebook).

Name of line______________________________ kv

No. of line support. Noticed faults and abnormalities: ______________

____

(write in detail)

____

____

____

Condition of wayleave: ______________________________

____

____

____

Inspection carried out from support No.______________ to support No.

"______" ______________, 196___ by patrolman ______________
(day) (month)

Report accepted "______" ______________, 196___
(day) (month)

Signed by______________

Back from a round of the line, the patrolman reports to his superior and enters the notes from his Patrol Report in a special log-book kept at the patrol post or at the line-service station. The original of the Patrol Report is sent to the district office, and the carbon copy is left in the patrolman's notebook.

Follow-up entries are made in the log-book after the faults and abnormalities detected by the patrolman have been remedied.

Minor defects on the lower parts of supports, such as, loosened bolted joints and wire bindings, loose warning sings, etc., are fixed by patrolmen. They should by no means climb supports, for even if the

line is dead, it may be closed at any instant. Patrolmen should never walk under the conductors, but a short distance away from them.

When a broken conductor is discovered, the patrolman should post guards within at least 8 to 10 metres of the broken conductor, warning the guards that closer approach is dangerous to life. If there is no one to put on watch, the linesman should remove the warning notices from the nearest two or three supports, put them up near the broken conductor, inform the district office of the break by telephone, return to the break, and wait for an emergency crew to arrive.

Special inspections. Inspections of this nature are made after wind storms, heavy rains, thunderstorms, etc. Their purpose is to detect any damage or breakage on the line and to take the necessary measures.

Special inspections should also be made after severe frosts, as the sharp drop in temperature may result in the breaking of separate strands in a conductor, porcelain insulators, etc., due to increased tension. Night inspections for corona, surface leakage, and overheated conductor joints also come under this heading.

Special inspections are conducted by appointed crews under an engineer.

Emergency inspections. Emergency inspections should follow each automatic trip-out of a line, irrespective of whether it has been reclosed or not to locate and identify the fault and estimate the amount of repair involved.

Emergency inspections are conducted by emergency crews. In the most serious cases, and on especially vital lines aircraft may be used.

Support-head inspections. Many faults on the lines, including conductors damaged by clamps, fine cracks in the insulator porcelain, and defects in suspension fittings, can only be discovered or seen by climbing the supports, which is known as support-head inspection. This inspection may only be sanctioned or ordered by the system's engineer in charge at least every year.

This inspection requires that the line be dead. In order not to interrupt service for any appreciable interval of time, this work is performed by a large number of crews under an experienced foreman, technician, or engineer.

These inspections also include minor line repairs and replacements.

Check inspections. These inspections are conducted by engineering personnel as a check on the condition of the wayleave and the line and the efficiency of the patrolmen. The results are summed up in a check inspection report which lists all the defects and faults revealed, estimates the scope of the necessary repairs and fixes the dates by which the work must be completed.

86. Maintenance Tests on Overhead Lines

In addition to inspections, overhead lines are given regular tests and checks as part of preventive maintenance.

After six years in service, wood-pole supports, stub poles and cross-arms given preservative treatment at a factory are tested for decay due to fungi.

The underground parts of metal supports are tested at random every six years.

Insulators on lines up to 35 kv are tested every three years; insulators on lines over 35 kv, every 6 years.

The resistance of joints on copper conductors is measured at random every six years; in aluminium and steel-cored aluminium conductors, every three years, and of bolted and composite joints between a copper conductor and an aluminium or steel-cored aluminium conductor every year.

The insulators and conductor joints on newly erected overhead lines are tested during the first year of service. Conductor joints across which the voltage drop or resistance is twice the voltage drop across or resistance of an equal length of solid conductor should be replaced.

Decay testing of wood-pole supports. Pole decay is due to fungi whose growth is supported by the moisture of the atmosphere and the upper layers of soil.

To protect wood poles from decay, they are treated with various preservatives. This preservative treatment is sometimes called fungi-proofing. It considerably extends the service life of wood-pole supports, makes them more reliable in service, and very significantly reduces repair work and, consequently, line outage time.

A very efficient method is tank treatment when the poles, after seasoning, are treated in a special plant. As a matter of record, the most important lines which operate at 20 kv or higher and transmit large blocks of power only use, if at all, tank-treated wood-pole supports.

What is termed local or brush treatment is less effective.

A decay test consists of a visual inspection, hammering, and measurement of the depth of decay.

In a visual inspection the poles are examined for rotten spots and areas, and cracks.

Hammering indicates whether or not the core of the wood is rotten. A clear ring is an indication of healthy wood, while a hollow ring is a sign of decay. Hammering is best done with a 400-gram hammer in dry unfrosty weather, because moist or frozen wood distorts the sound.

If inspection and hammering reveals decay, its depth is measured with a probe or an ordinary 10- or 12-mm drill at the most critical

sections of each part and at the points of greatest decay. In vertical or inclined parts, such as stub poles, vertical braces, X-braces, etc., the depth of decay should be measured at three points spaced at 120° round the circumference. Horizontal parts, such as cross-arms, lateral braces, etc., should be measured at two points round their circumference.

The probe should be forced into the wood by hand. Neither a hammer nor any other tool may be used for the purpose.

When an ordinary drill is used, the depth of decay is measured between the points where rotten borings begin and stop to come out.

All holes made during a decay test should be treated with antiseptic paste and plugged with impregnated dowels.

The results of the decay test are entered in a check-list.

Checking metal supports for corrosion. Rust on metal supports is most likely to be formed at the joints and the horizontal members owing to accumulation of dust and moisture. Underground parts are also liable to corrosion. The extent of damage to the metal by corrosion is determined by measuring the remaining cross section of the part. For this, the metal should be cleaned of rust and several measurements taken.

Special attention should be paid to the condition of paintwork on the metal parts above the suspension insulator strings, as rust washed down from them by dripping water tends to deposit on the porcelain insulation, thus impairing its insulating capacity.

Metal supports near sea shores, large thermal power stations, chemical plants and steel works are more subject to corrosion than supports in other districts and therefore require frequent and closer inspection.

Conductor vibration control. The vibration of overhead conductors is caused by wind eddies which produce standing waves in conductors from one to 20 metres in length and several centimetres in amplitude within a span. Tests have shown that the frequency of vibration depends upon conductor diameter and wind velocity. The frequency is usually 10 to 50 cycles per second.

Vibration results in fatigue of the conductor metal, breakage of its strands and the consequent failure of the conductor as a whole, usually at clamps.

Vibration also causes damage to the insulators, cotter pins, line fittings and, in some cases, line supports.

Periodic inspection and timely repair play a major part in preventing damage to conductors by vibration.

Overhead lines are protected against conductor vibration as follows:

(1) by reducing the resultant mechanical stresses due to vibration much below fatigue limit stresses;

(2) by stopping or damping vibration to safe limits by means of armour rods and dampers attached to conductors.

Ice control. Ice will form on conductors over a small temperature range close to 0°C, due to sleet or glazed frost, when a thaw is followed by a drop in temperature.

In the majority of cases the temperature at which ice will form will be between 0° and minus 3°C and may be as low as —6°C.

Intensive ice formation may result in extreme loads which may break conductors.

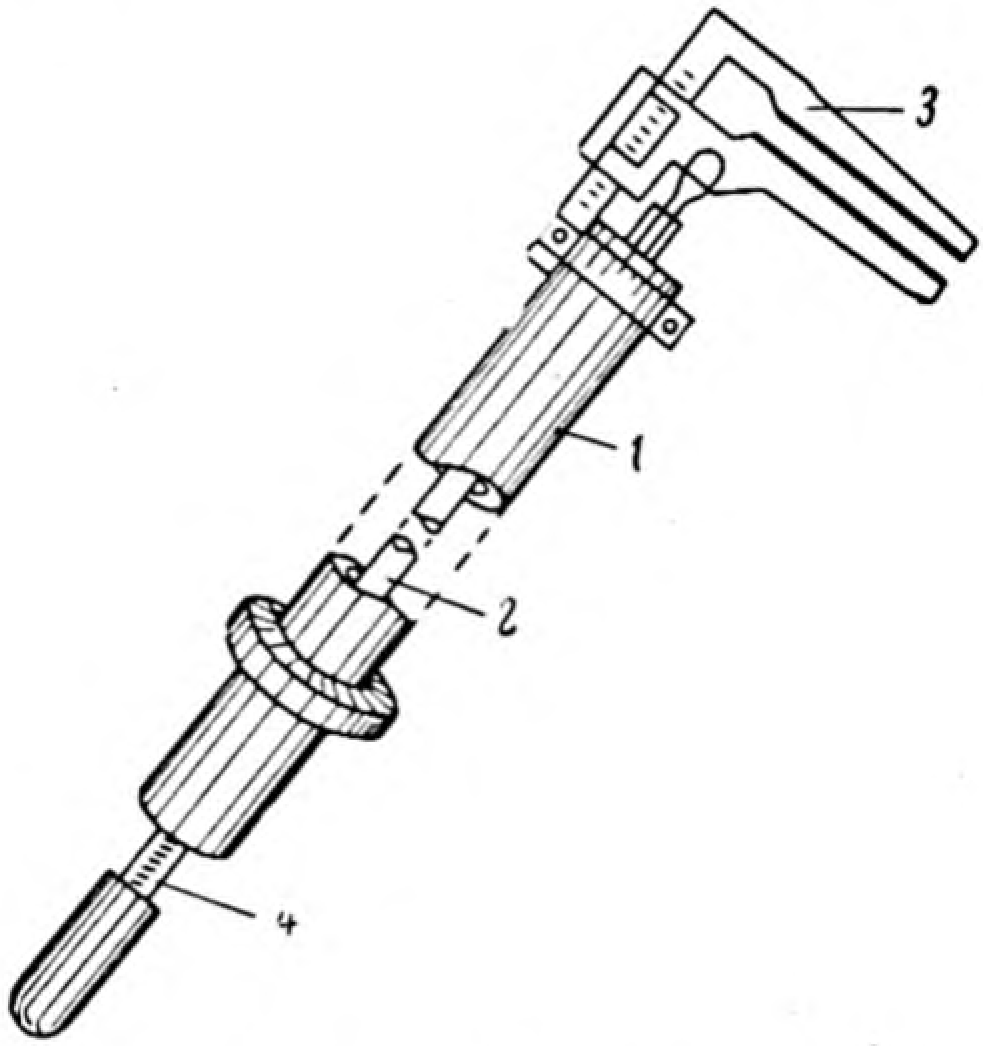


Fig. 322. Ice thickness gauge

To be ready for ice control, it is good practice in areas subject to heavy ice formation to keep watch on the weather conditions under which ice will form, and on the process of ice formation on the lines.

Ice formation on conductors can be controlled by heating the conductors with load or short-circuit currents (ice melting), and by mechanical methods.

When conductors (or earth-wires) are heated with a current, the current density is raised to a point where enough heat is developed in the conductor to melt off the ice. This can be done as follows:

(1) by transferring loads from other lines to the line in trouble;

(2) by short-circuiting the dead line at one end and sending the necessary current from the other;

(3) by connecting transformers in opposition.

Mechanically, ice from conductors and earth-wires can be removed by:

(a) knocking the ice off with long poles of bamboo, wood or bakelised paper;

(b) working the ice off with cords (for example, a synthetic-fibre cord), etc.

An ice thickness gauge for work on "hot" overhead lines (Fig. 322) operates on the principle of a caliper. It consists of three lengths of bakelised-paper tubing *1* of 45 mm O.D. and 25 mm I.D. within which a 15-mm diameter bakelised-paper tube *2* is placed, also consisting of three members joined by couplings. The caliper *3* is fitted at the top end of the tube. The gauge has somewhat elongated jaws. The movable jaw is affixed to the inner bakelised-paper tube.

The scale *4* is drawn on the lower retractable end of the inner tube. The gauge is 6.5 metres long.

Measuring the clearances of overhead lines. Conductor clearances should be checked periodically as they may be changed by a variety of service factors.

The most common among them are conductors slipping in suspension clamps due to unequal tension in adjacent spans or elongation with time; tilted or displaced supports after a repair; change in length of a suspension string due to replacement by a different type or number of units; construction of new roads under or near the line; reconstruction of existing structures, electric power lines, earth embankments and other engineering installations.

Line clearances may be determined with the aid of a theodolite, or with some other special instrument adapted for work on hot lines (Fig. 323). One instrument consists essentially of a tripod *1*, sighting tube *3*, reading scale *6*, reading arm *7* and plumb-bob *8*.

The tripod legs, 1.5 to 1.6 metres long, and the sighting tube are pivoted at the top with a bolt *2*. The sighting tube is fitted with an eye-piece *4* (a bushing with a hole in the centre) at one end; and with crosshairs *5* at the other (formed by two threads which intersect at the axis). The tube may be replaced by a sighting frame constructed from strip steel and provided with an eye-piece at one end and a crosshair at the other. The reading arm *7* is secured at right angles to the sighting tube. Readings are taken from the scale *6* against the index string in the slot in arm *7*.

In use the instrument is set up with the reading scale placed horizontally by the plumb-bob *8*.

When the horizontal distance from the instrument to the point the tube is trained at is 25 metres, one metre of vertical distance will correspond to 1 cm on the reading scale.

Line insulator inspection. During service on an overhead line, insulators are subject to mechanical and electrical stresses which shorten their service life and cause damage.

Decrease in mechanical and electrical strength (deterioration) of insulators is further caused by vibration and temperature changes, or they may be originally faulty due to poor porcelain and glaze, poor cement joints around suspension pins, and poor cement.

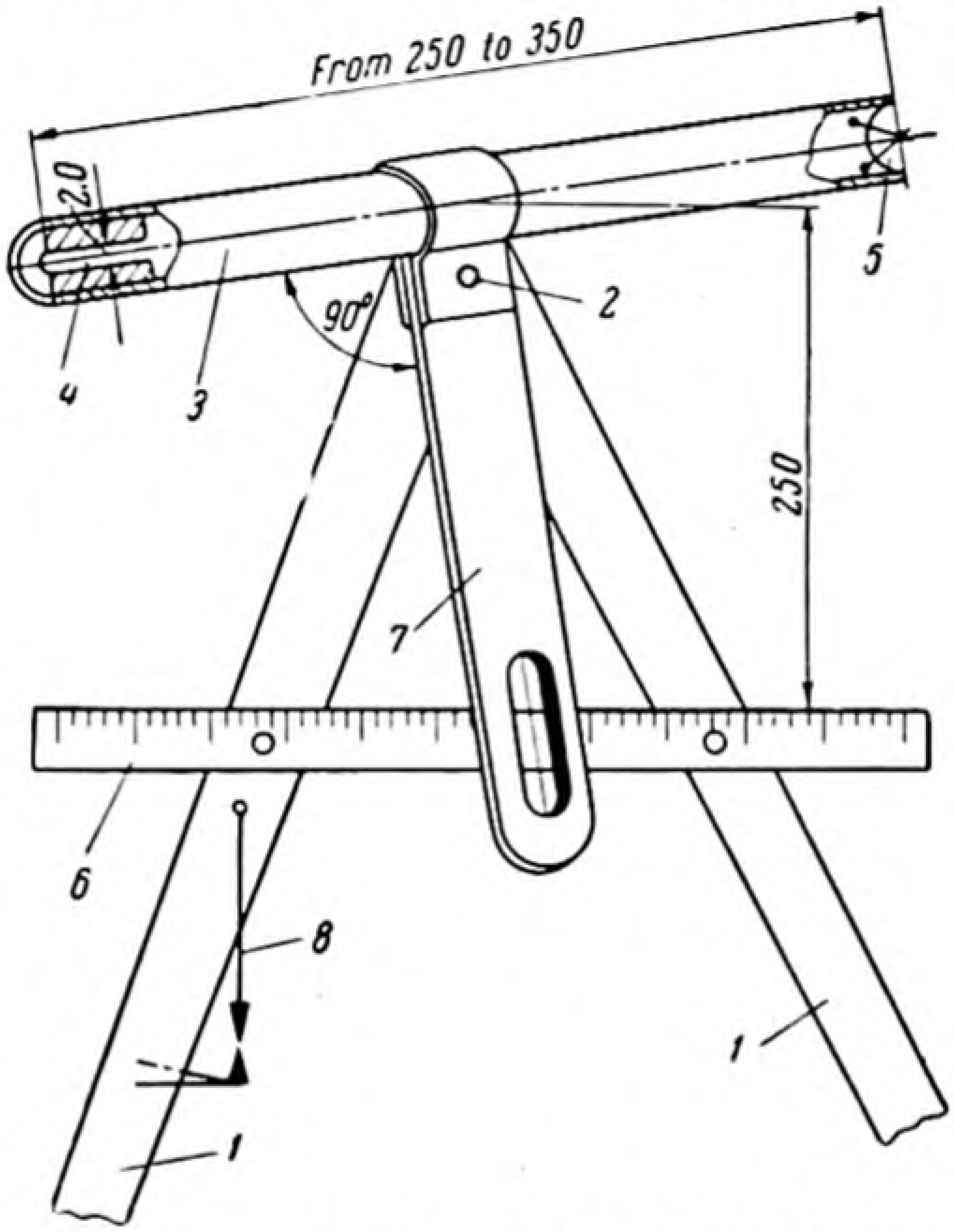


Fig. 325 Angle-measuring device adapted for clearance measurement without de-energising the line

Stressing mechanically beyond their design strength or excessive voltages (overvoltages) likewise lead to failure of insulators, as does dirt on the porcelain.

Defective insulators are detected for replacement by means of an insulator grading stick or by applying test voltages during a round of special inspection. Measures to detect faulty insulators are likewise taken during periodic inspections and patrolling.

Whenever defective ("zero-voltage") insulator units are detected in a string, they should be replaced as soon as the line can be switched off.

Inspection of joints. Joints deteriorate in service with time to a point where they may lose some of their conductivity due to short circuits

which cause considerable heating and impair contact between the parts of a joint, and to corrosion on the contact surfaces which causes redistribution of current through the cross-sectional area of a joint and, as a corollary, the burning-through of some of its elements.

Poor jointing, dissimilar metals in a joint, improper type of connector for a given conductor and similar causes combine to bring about the failure of joints. Poor electric contact or low mechanical strength in a joint may lead to the overheating and breaking of a conductor.

Defective joints are detected and replaced during special inspections and also during periodic day and night patrolling, to timely avert a breakdown or line outage. The absence of snow or ice on a joint when they are present on the conductor, or a red-hot connector or conductor seen in the dark indicate poor contact in the joint.

Since the voltage drop across a joint is directly proportional to its resistance, the quality of the joint can be judged by the ratio $\frac{V_c}{V_n}$, where: V_c is the voltage drop across the joint being checked and V_n is voltage drop across a piece of conductor as long as the joint.

In addition, the conductivity of joints is regularly measured as part of preventive maintenance.

Joints can be tested:

(1) with direct current on dead lines;

(2) by using special testers to measure the voltage drop on "hot" lines.

Inspection of conductors and overhead earth-wires. In service, conductors and earth-wires are subjected to tensile stresses due to their pull, to compressive stresses in the clamps and to bending stresses at the clamps, all this affecting the condition of conductors and earth-wires.

Their condition may also be inherently affected by poor welded joints in the individual strands, poor galvanising, and inferior workmanship in stringing (kinks, crushed spots, torn and notched strands, disturbed galvanised coating, overtensioning, etc.).

As a result, some strands and a conductor as a whole may break, especially where it is secured in clamps on line supports, or somewhere in mid-span. Because of this, conductors must be regularly inspected at their clamps, in particular at suspension clamps where some of the strands may break as a result of fatigue due to vibration. This happens less often in tension clamps and in joints.

Broken strands in a conductor are difficult to detect by visual inspection without taking it out of the clamp. Therefore conductors should periodically be taken out of their suspension clamps at random wherever local conditions require such inspections.

87. Line Repair

Overhead lines may be given either routine repair or overhauls.

The aim of routine repair is to maintain the line and its auxiliary structures at the necessary level of operational reliability.

The aim of overhauls is to fully restore a damaged line and its auxiliary structures to their necessary strength. Overhauls are performed when the necessity for them arises and are scheduled on the basis of inspections, measurements and tests.

Repair work may be carried out:

(a) on dead lines which should be fully cleared, opened, and earthed;

(b) on a line in which only the phase to be repaired is opened;

(c) on a "hot" line.

Before any repair is commenced, the crew assigned to do the work should be briefed on the rules of work and safety. If the work is to be done on a hot line, personnel should undergo training exercises in addition to their instructions.

Repair work may be performed:

(a) by a crew assigned only some of the repair operations, or either on the ground or aloft;

(b) by a crew assigned all repair on a section of a line;

(c) by a crew assigned all repair over the entire line or even lines.

Repair work is generally performed by line maintenance personnel. When the scope of the work is large, it is done under a contract with a specialised repair organisation.

The actual repair work to be done on an overhead line is scheduled on the basis of the data obtained through inspection and maintenance checks, giving priority to troubles threatening normal operation of the line. Any fault fraught with an outage should be remedied on an emergency basis.

Scheduled line repairs include:

(a) replacement of damaged or heavily decayed parts of wood-pole supports;

(b) replacement of defective supports as a whole;

(c) preservative treatment of wood-pole footings;

(d) painting of metal supports;

(e) replacement of damaged insulator units and strings;

(f) replacement of line fittings;

(g) cutting-out and replacement of damaged conductor sections;

(h) replacement of conductors and overhead earth-wires on some line sections;

(i) sag adjustment on conductors and overhead earth-wires;

(j) repair of earthing conductors run down the supports;

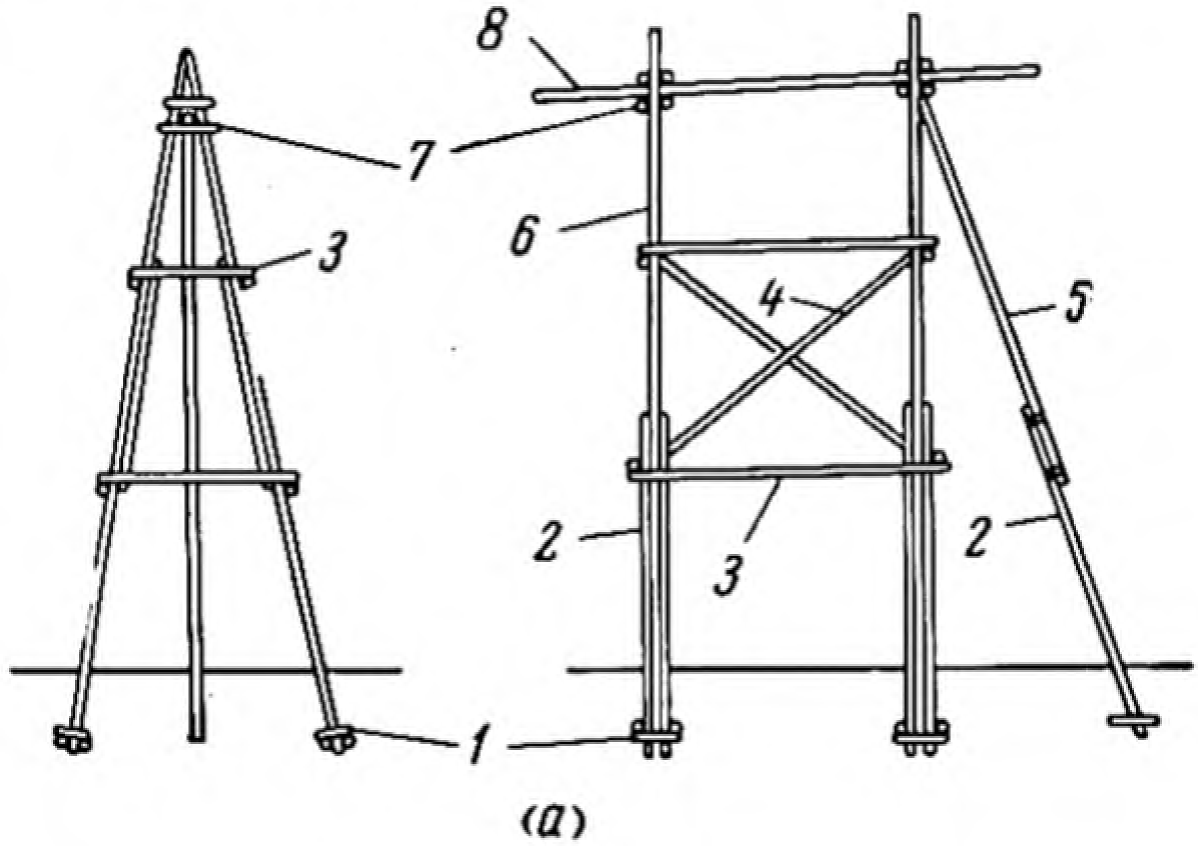
(k) repair of lightning arresters.

For the most part, line repair is performed on dead lines by the same methods as are used for initial installation (see Ch. 9). In some cases, however, it is important that repair will not interrupt the service. To meet this need, especial "live-line" methods and tools have been devised whereby a line may be repaired while it is hot. They are discussed below.

88. Repair of Hot Overhead Lines

Repair on a hot overhead line may include:

(1) inspection and repair of conductors, insulator strings and fittings (on 35- to 220-kv lines);



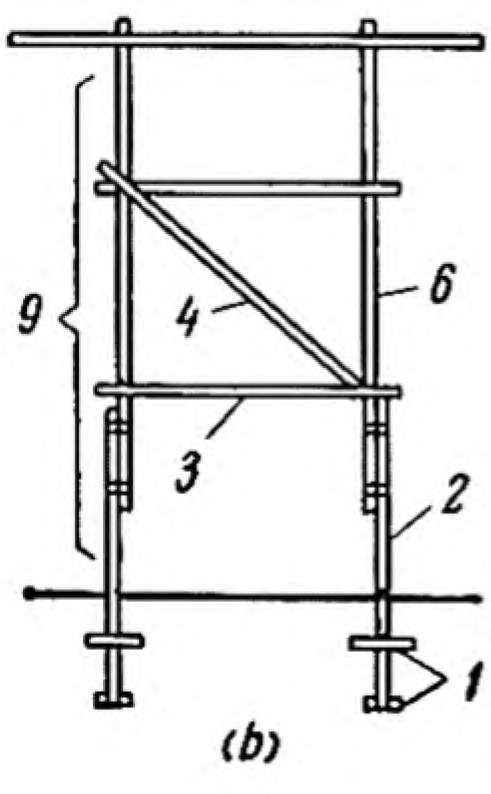


Fig. 324. Parts of wood-pole supports for 35 to 100 kv overhead electric power lines:
a—angle support; *b*—intermediate support; *1*—crib braces; *2*—stub pole; *3*—horizontal brace; *4*—angle brace; *5*—stay pole; *6*—leg pole; *7*—cross-arm support timber; *8*—cross-arm; *9*—support leg

(2) replacement of wood-pole support parts (Fig. 324), straightening of anchor and intermediate supports, and complete replacement of intermediate supports (on 35- to 110-kv lines);

(3) mounting and demounting of expulsion protector tubes (on 35- to 110-kv lines).

Repair work on a hot line or phase calls for the use of "live-line" equipment and tools, such as safety ladders, telescopic towers, safety platforms, "hot" sticks, live-line clamps, etc.

An insulated ladder (Fig. 325) consists of a top platform on which the linesman can stand, an insulating section serving to isolate the linesman from earth, a base on which the ladder proper is mounted, and a winch to lift and extend the ladder.

The top platform is furnished with a live-line clamp and an extendable frame.

Fig. 326 illustrates how the metal platform is electrically connected by means of the live-line clamp fitted on a special stick 0.7 to 0.8 metre long. The platform is automatically

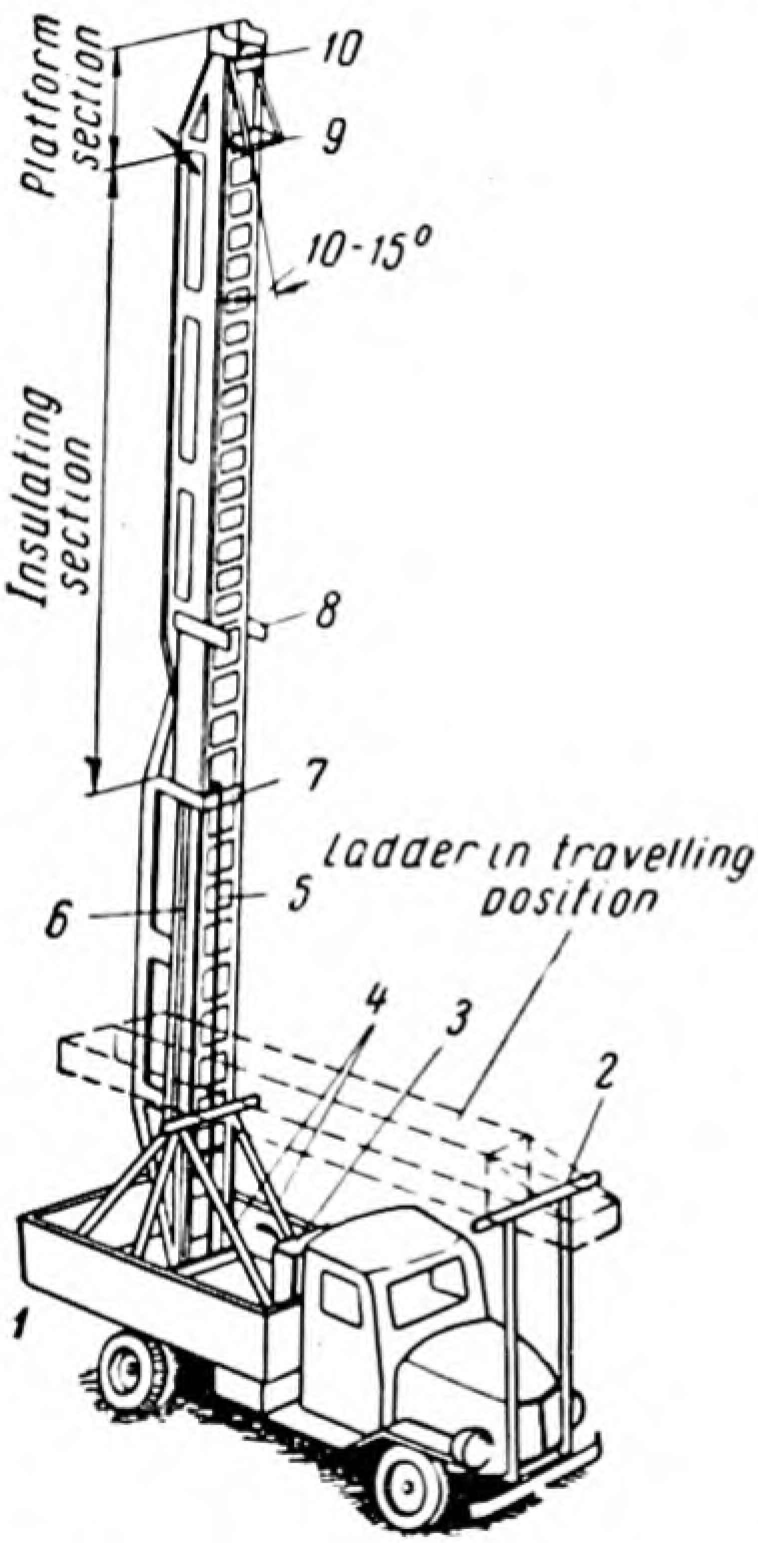


Fig. 325. Double-section insulated ladder:

1—jack; 2—front support frame; 3—raising-extending winch; 4—ladder base; 5—ladder-extending wire rope; 6—latch frame; 7—middle bracing; 8—upper bracing; 9—metal platform; 10—tool box

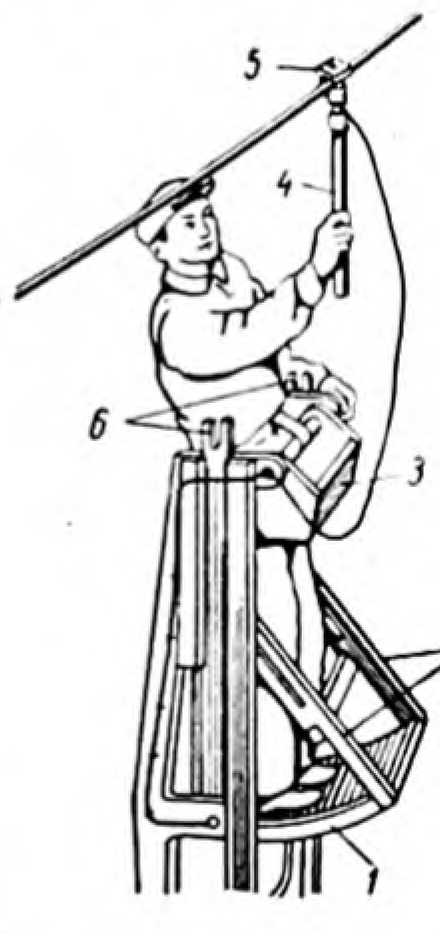


Fig. 326. Platform of insulated ladder equipped with the live-line clamp:

1—metal platform; 2—strain members; 3—tool box; 4—insulating stick; 5—live-line clamp; 6—extendable frame

retracted when the ladder is lowered and swings out when the upper section is extended.

The extendable frame built into the platform terminates in a metal roller free to rotate on a shaft (Fig. 327).

The extendable frame is used where:

(a) the distance between the top platform and the live-line element should be 1.75 to 2 metres;

(b) the safety ladder is required to bear the weight of a conductor up to 200 kg.

A safety platform is used when a linesman working close to a support should be able to touch live parts.

It consists essentially of a cradle (Fig. 328) equipped with a live-line clamp, an insulating support assembly (main frame and strain rods) and a swivel assembly.

Suspension link sticks are employed when a string of insulators has to be replaced on overhead lines operating at up to 110 kv.

The live-line suspension link sticks shown in Fig. 329*a* are employed to replace suspension insulator strings and to take conductors out of their clamps for inspection.

Tension insulator strings are replaced with the aid of link sticks such as shown in Fig. 329*b* and *c*.

Repair work on wood-pole supports, with the line hot (and the conductors arranged in horizontal configuration on 35- to 110-kv lines) includes replacement of parts on AH-type supports, such as stub poles, horizontal and X-braces, stays, cross-arms, cross-arm support timbers (Figs 330 and 331), and also complete replacement of H-type supports. Here is an example of stub pole replacement on 35- to 110-kv lines.

Depending upon support design, the stub poles may be replaced with the aid of blocks, crowbars, substitute poles, or tripods.

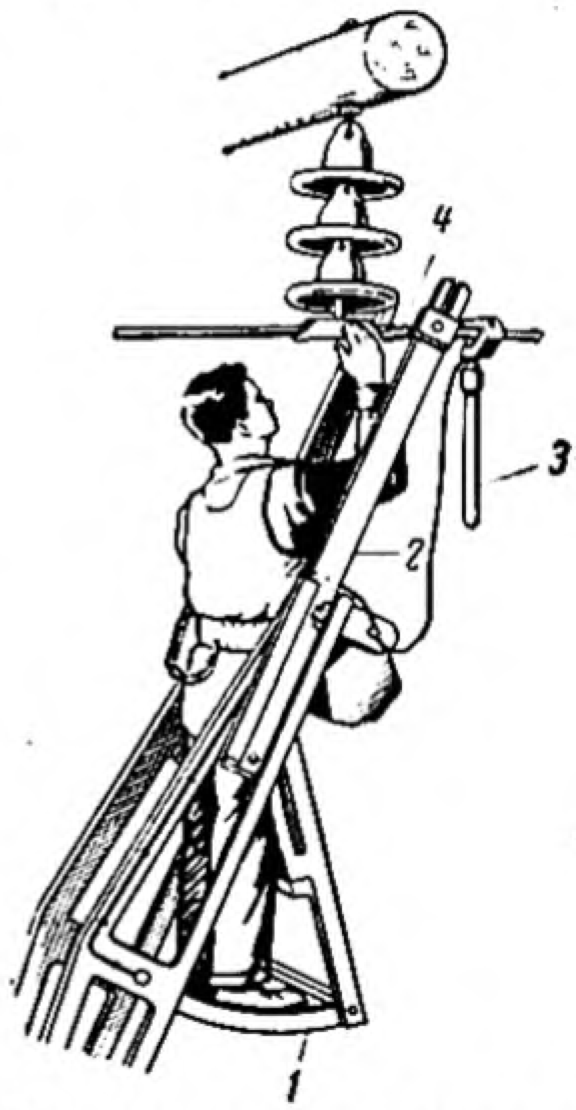


Fig. 327. Platform of an insulated ladder equipped with its extendable frame raised: *1*—platform; *2*—extendable frame; *3*—stick fitted with live-line clamp; *4*—roller

A pole whose stub is to be replaced is set on a blocking of railway sleepers. In the case of H-type supports the pole is also strutted to the other pole by a cross timber and is guyed by ropes.

The sleepers in the blocking are held together and to the pole by timber staples (Figs 330 and 331).

On an H-type support the pole to be repaired should first be guyed and then connected by a strut at a height of 3 to 4 metres to the other pole before a block may be wedged at its butt. After the strut and guy ropes have been finally secured, the stub pole is dug out and pulled from the hole with the aid of a rope pulling mechanism (Fig. 332).

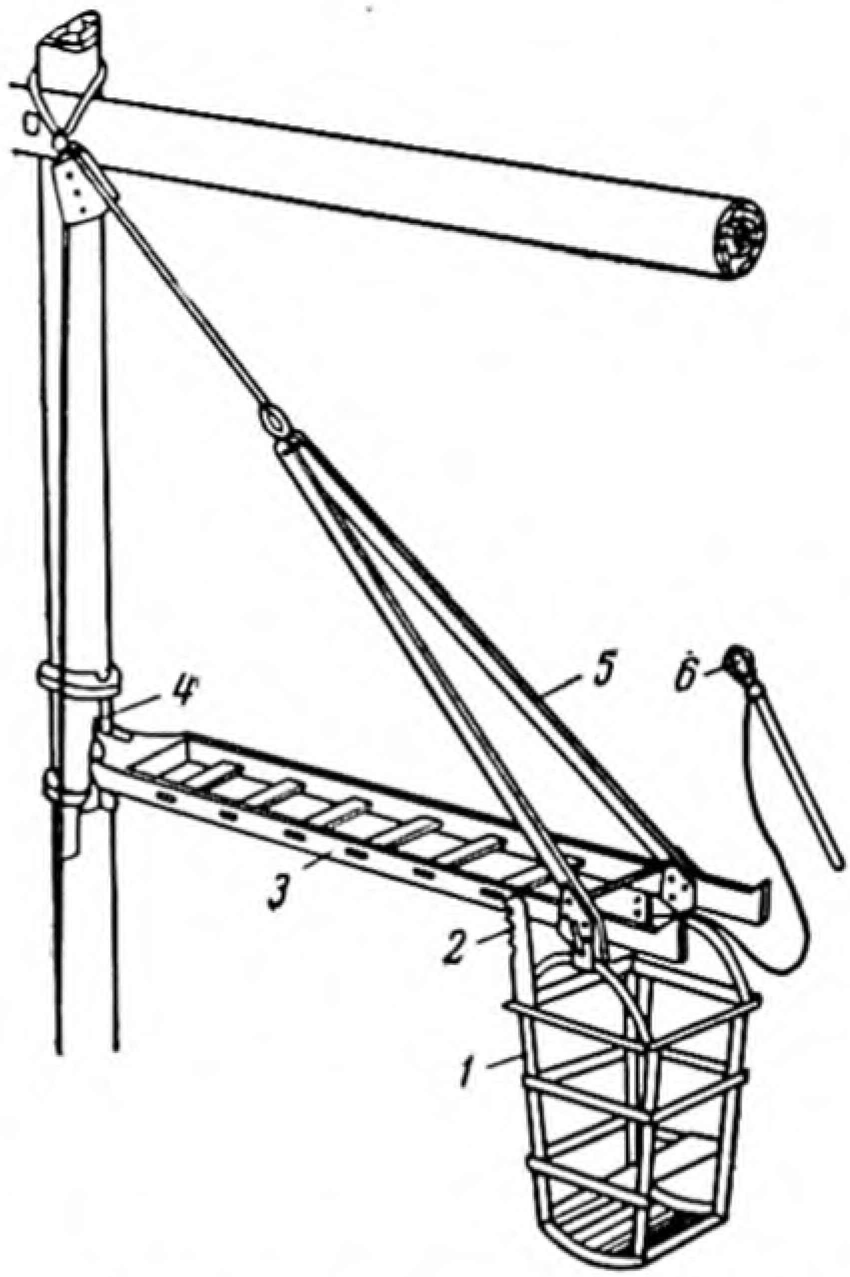


Fig. 328. Swivelling insulated safety platform, or a cradle (linesman works standing):

1—cradle; *2*—cradle latch arm; *3*—main frame; *4*—attaching-swivel assembly; *5*—strain rods; *6*—live-line clamp

The new stub footing is put in place by hand and secured to the pole by wire bindings, after which the earth is firmly rammed back into the hole.

On 35-110-kv lines cross-arms of H-type supports which have no X-braces are replaced by lowering the old cross-arm and conductors to a temporary position down the poles. On 110-kv lines, the old cross-arm and conductors are lowered about 4.5 or 5 metres, on 35-kv lines about 3 or 3.5 metres. A new cross-arm is lifted in a vertical position near a pole leg, gradually turned horizontal, and then arranged on temporary brackets alongside the old cross-arm.

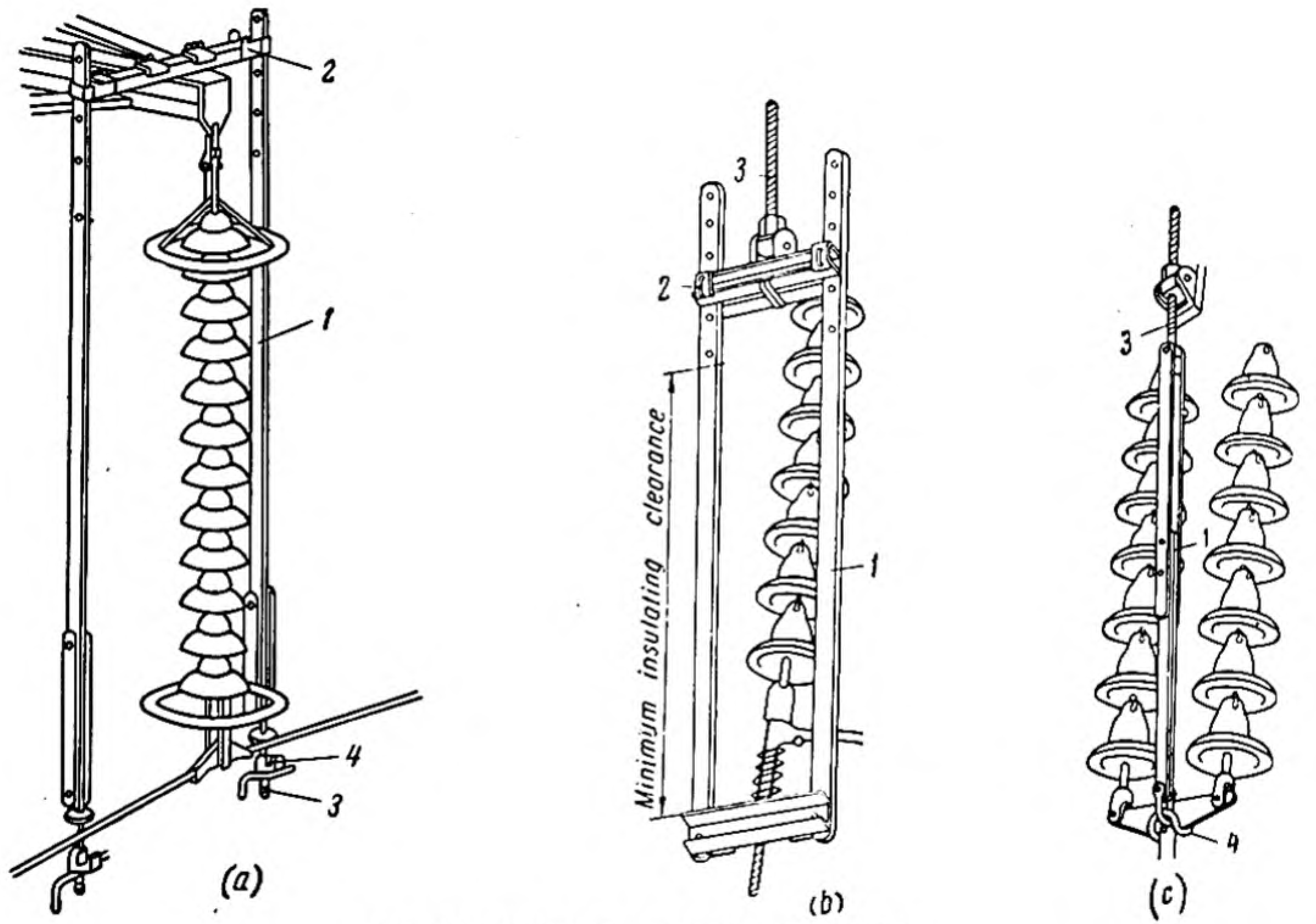


Fig. 329. Live-line suspension link sticks:

a—link sticks arranged on an intermediate line support, *b*—link sticks for replacing single tension strings; *c*—link sticks for replacing double tension strings: *1*—strain bar; *2*—upper cross member; *3*—clamping screw; *4*—engaging link

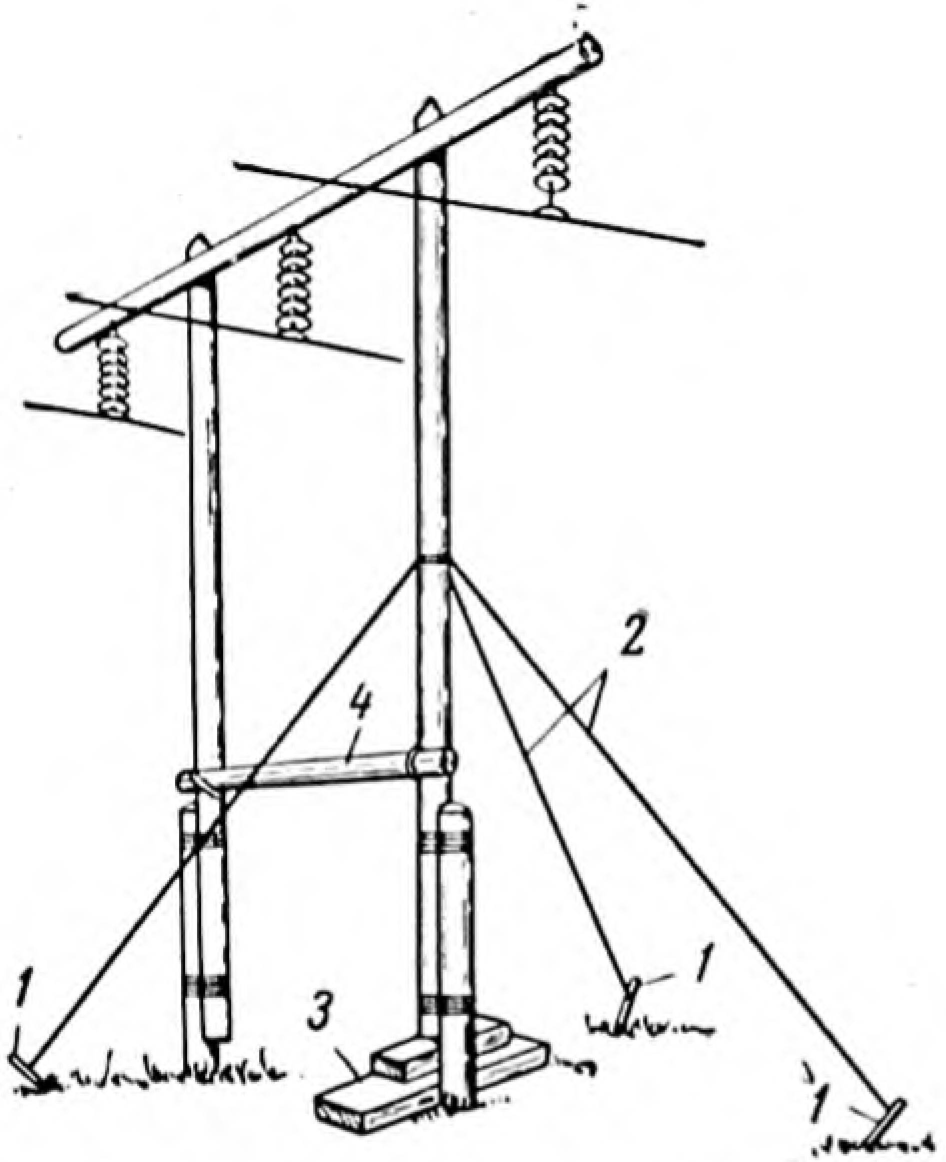


Fig. 330. Preparations for replacing stub pole on H-type support with aid of timber blocking:
1—guy anchor; 2—guy rope; 3—railway sleeper blocking; 4—bracing cross timber

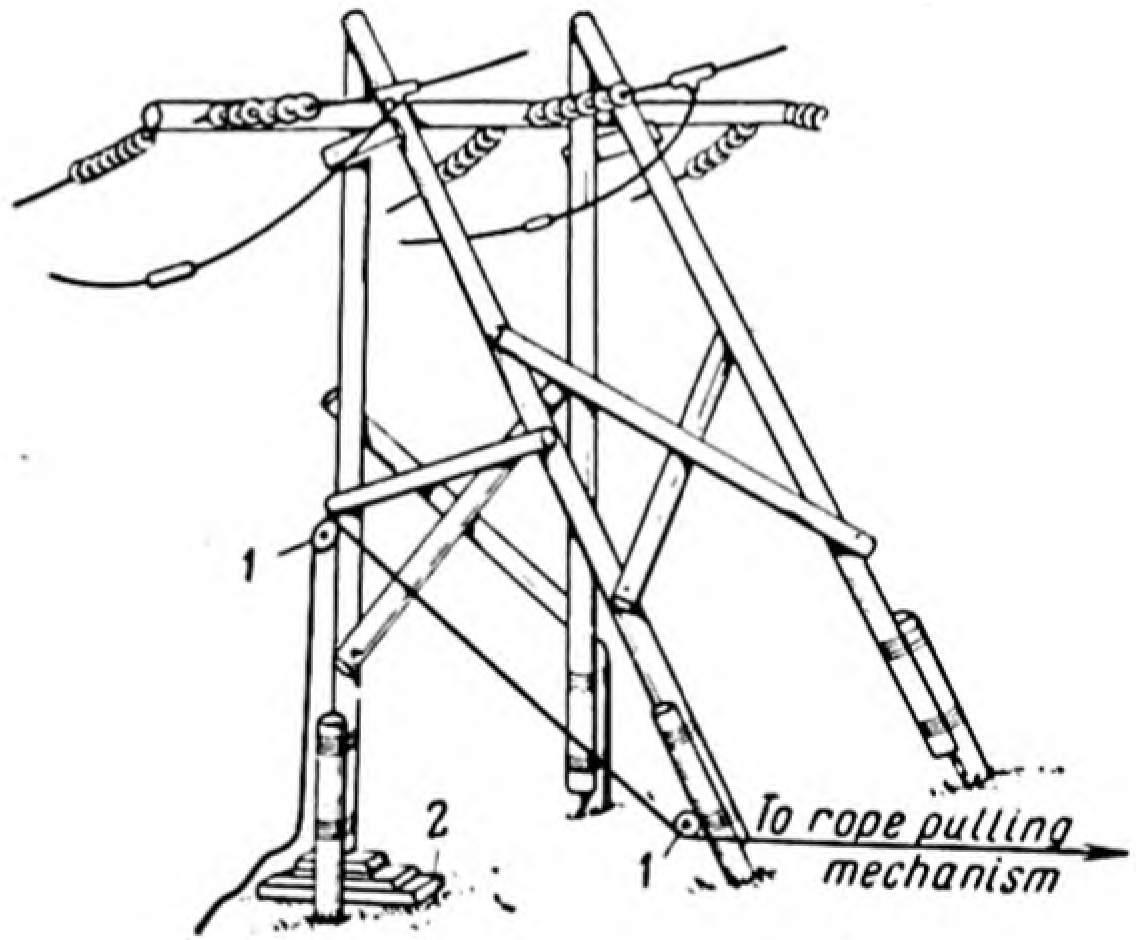


Fig. 331. Preparations for replacing stub pole on AH-type support with aid of blocking:
1—snatch block; 2—railway sleeper blocking secured with timber staples

After the insulator strings have been transferred from the old to the new cross-arm, the old cross-arm may be lowered to the ground and the new cross-arm put into its permanent position.

The procedure for cross-arm replacement is illustrated in Fig. 333. Two endless ropes passed over blocks (Fig. 333*a*) are attached to the support on the side opposite the old cross-arm. The upper blocks are

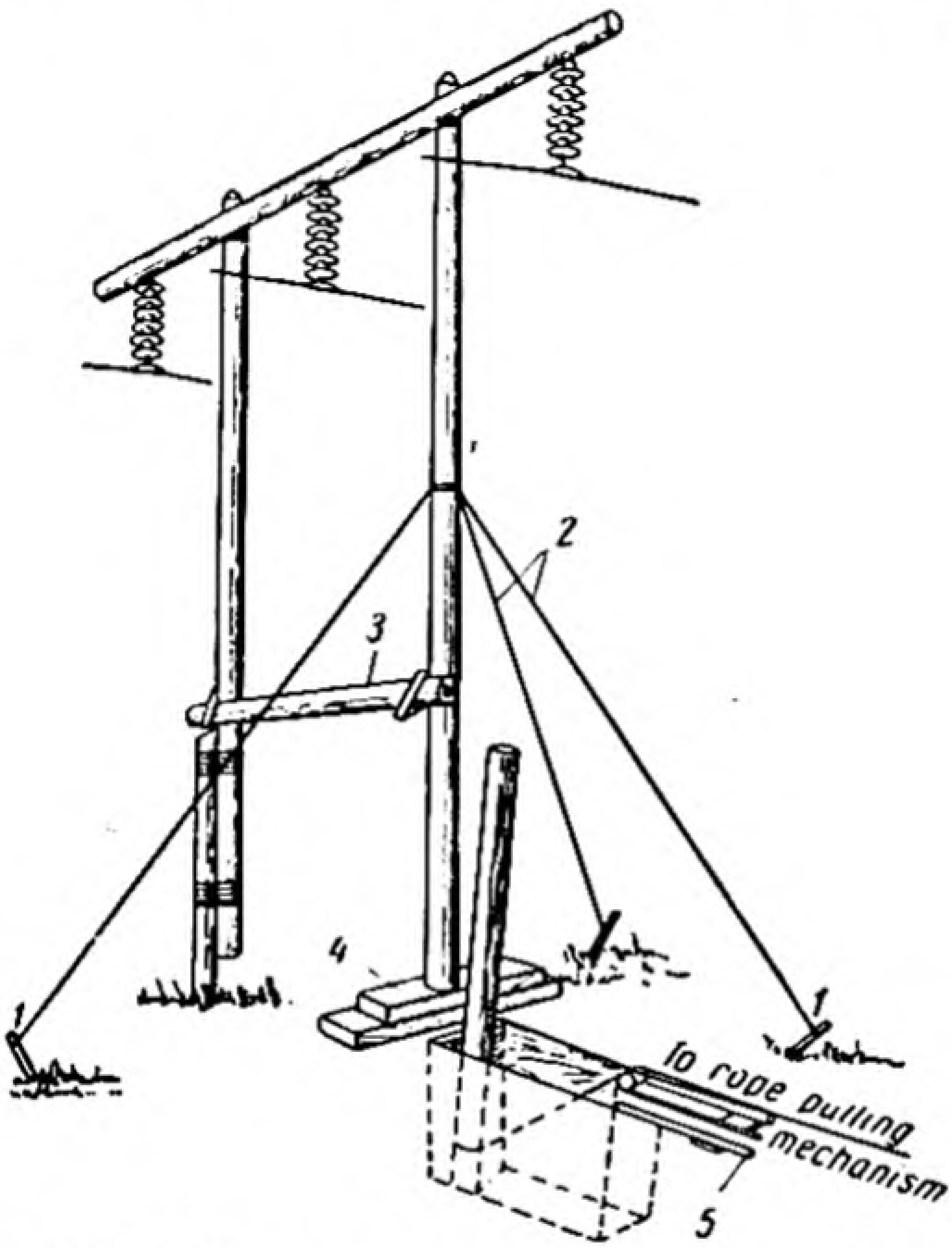


Fig. 332. Pulling old stub pole out of hole with aid of guide frame:

1—guy anchor; 2—guy rope; 3—bracing timber; 4—pads, 5—guide frame

secured to the cross-arm, and the lower blocks to anchors driven into the earth at an angle. After removing the bolts which hold the cross-arm to the poles, the cross-arm and conductors are lowered into the outer seats in the temporary brackets (Fig. 333*b*). Both the new and old cross-arms are clamped on the brackets by straps. Two linesmen take up positions on the cross-arms (one man lying, the other man standing near the support pole) and transfer the insulator strings from the old to the new cross-arm (Fig. 333*c*).

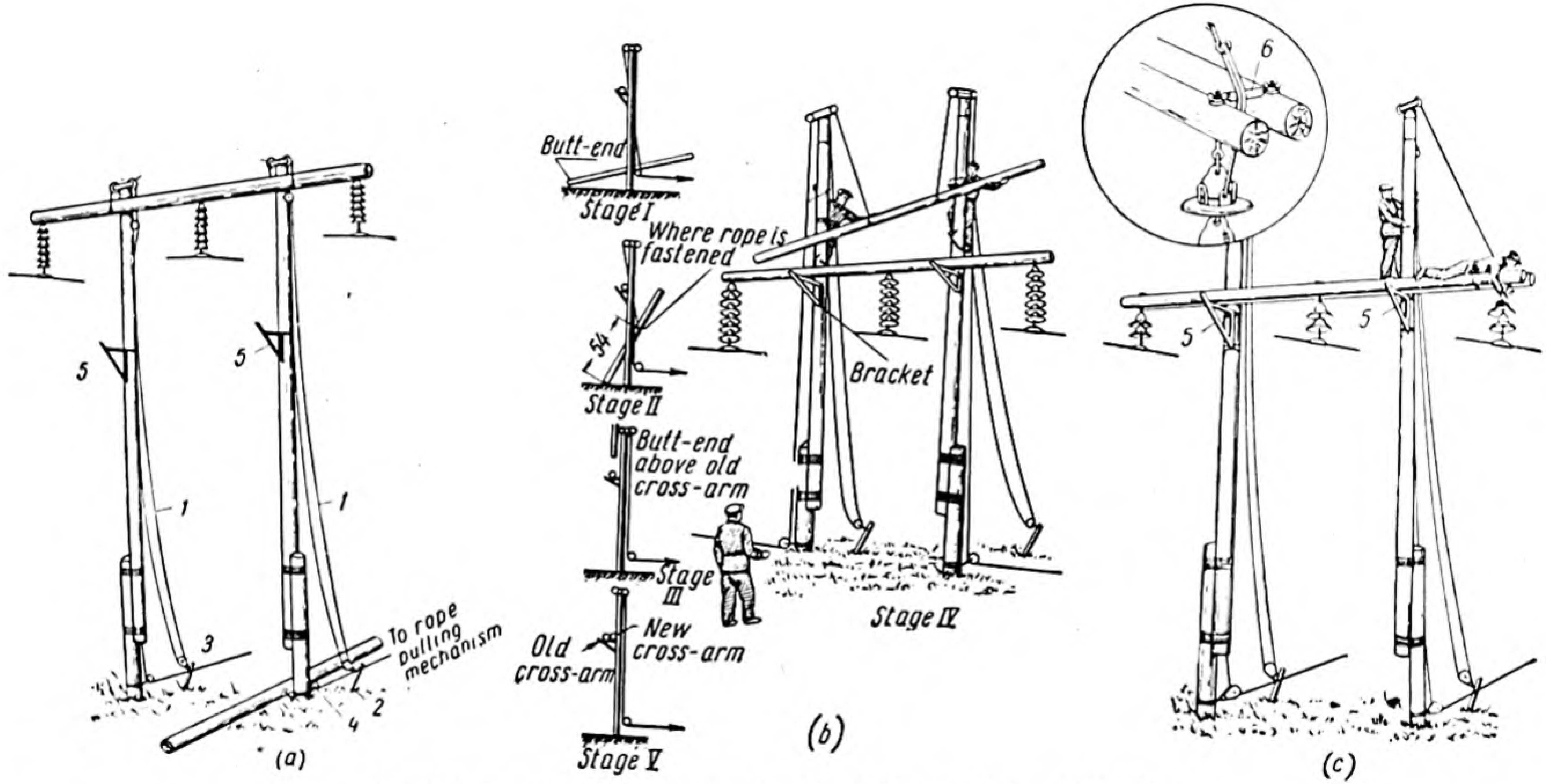


Fig. 333. Cross-arm replacement without de-energising of the line:
a — arrangement of tackle on a H-type line support; *b*—lifting of new cross-arm; *c*—transfer of insulator string: *1*—endless rope; *2*—anchor; *3*—lower tackle block; *4*—snatch block; *5* — temporary bracket; *6*—guide roller

By means of two lift ropes or tackle, the new cross-arm is then lifted into its permanent position (after lowering the old cross-arm to the ground) and secured to the support poles.

Repair work on hot overhead lines is subject to the Safety Regulations for Overhead Line Maintenance and acting instructions for the repair of hot lines with rated voltages of 35 to 220 kv.

Connection of tee-off lines to a hot 6-kv overhead lines. Connection of a branch line to (or disconnection from) a hot 6-kv line is subject to special instructions which specify the use of disconnecting devices and the following rules:

(a) all users supplied by the branch line under repair shall be disconnected from it;

(b) the conductors on the main overhead line shall be secured on pin-tipe insulators and arranged in the configurations shown in Fig. 334.

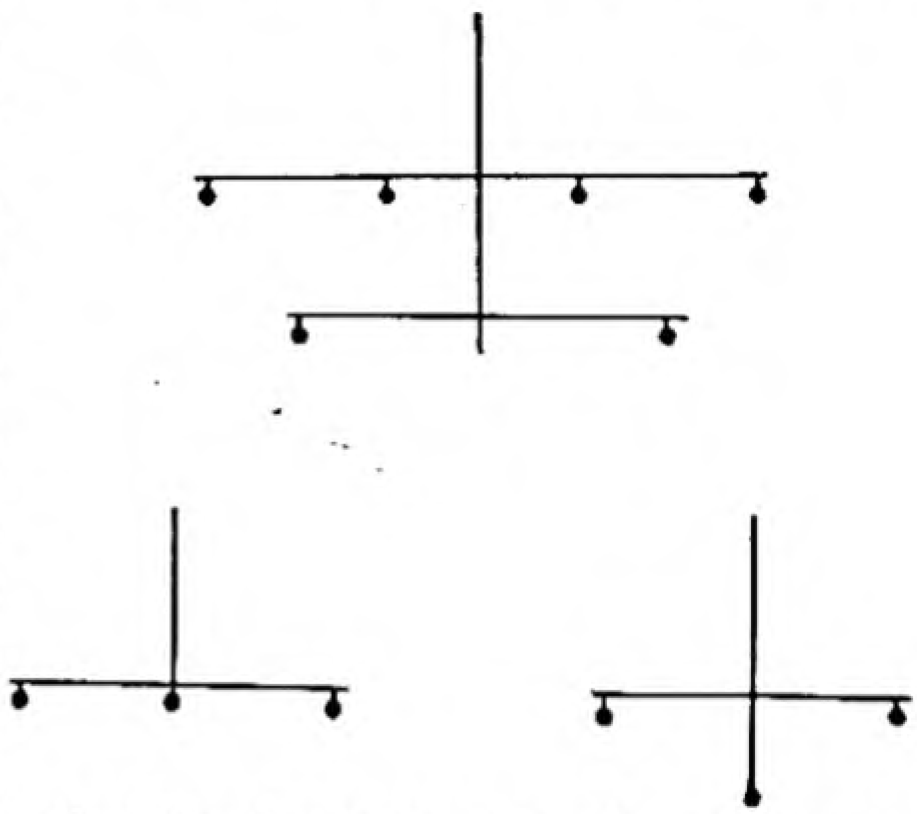


Fig. 334. Configurations of conductors on 6-kv main power lines for connecting tee-off lines, with main line energised

A tee-off line is connected to a main line via a disconnecting device. The latter is made capable of connecting a tee-off line to a hot 6-kv main line phase by phase and is rated for a continuous load current of 100 amperes. The disconnecting device is intended for pole mounting on intermediate supports of 6-kv lines and consists of:

(a) a steel split collar which has attachments for fixation to a wood pole and for receiving ШД-10 pin-type insulators (Fig. 335) mounted on cantilever brackets. The cross bar of this collar carries a ШС-6 insulator used to take the other, far-side conductor around the intermediate support;

(b) three ШД-10 pin-type insulators, the cap of each unit carrying a die-plate clamp, for the tee-off conductors. The upper (removable) plate of each clamp has a finger contact within a guide ring (Fig. 336). The latter is rubber-coated to protect the varnish coating on the insulated stick from damage in use;

(c) three telescopic links having an upper and a lower screw-type clamp (Fig. 337). These links are used as jumpers between the conductors of the main and tee-off lines. For this, the upper clamp of each link is placed on the respective main line conductor and the lower clamp on the respective finger contact solidly connected to one of the tee-off line conductors. The telescopic links are constructed

of two brass tubes 25 mm and 19 mm in diameter. The lower tube is shunted by a flexible copper cable. The upper screw-type clamp at the top of the upper tube can take conductors from 6 to 18 mm in diameter.

The lower clamp serving for attachment to the finger contact on ШД-10 insulators is located on the lower telescopic tube. At the lower

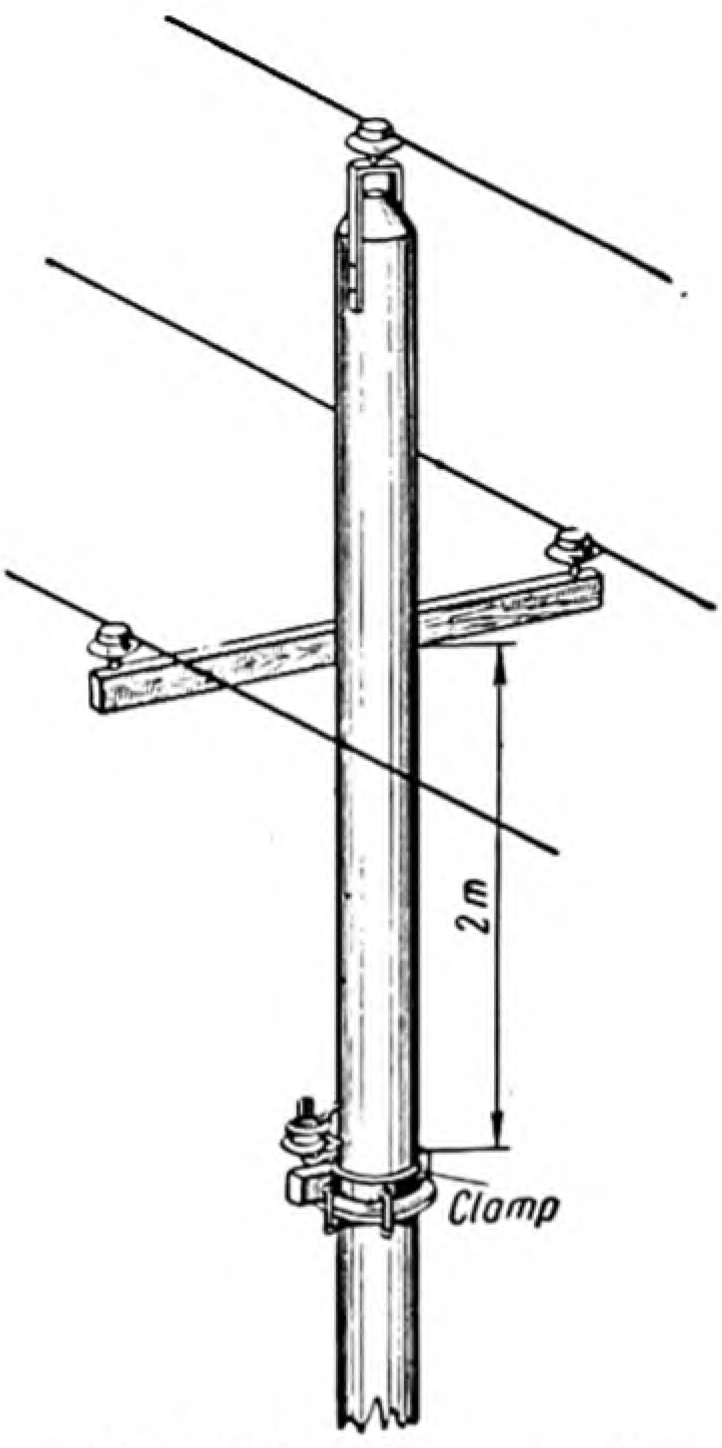


Fig. 335. Split collar secured on intermediate pole of main 6-kv power line

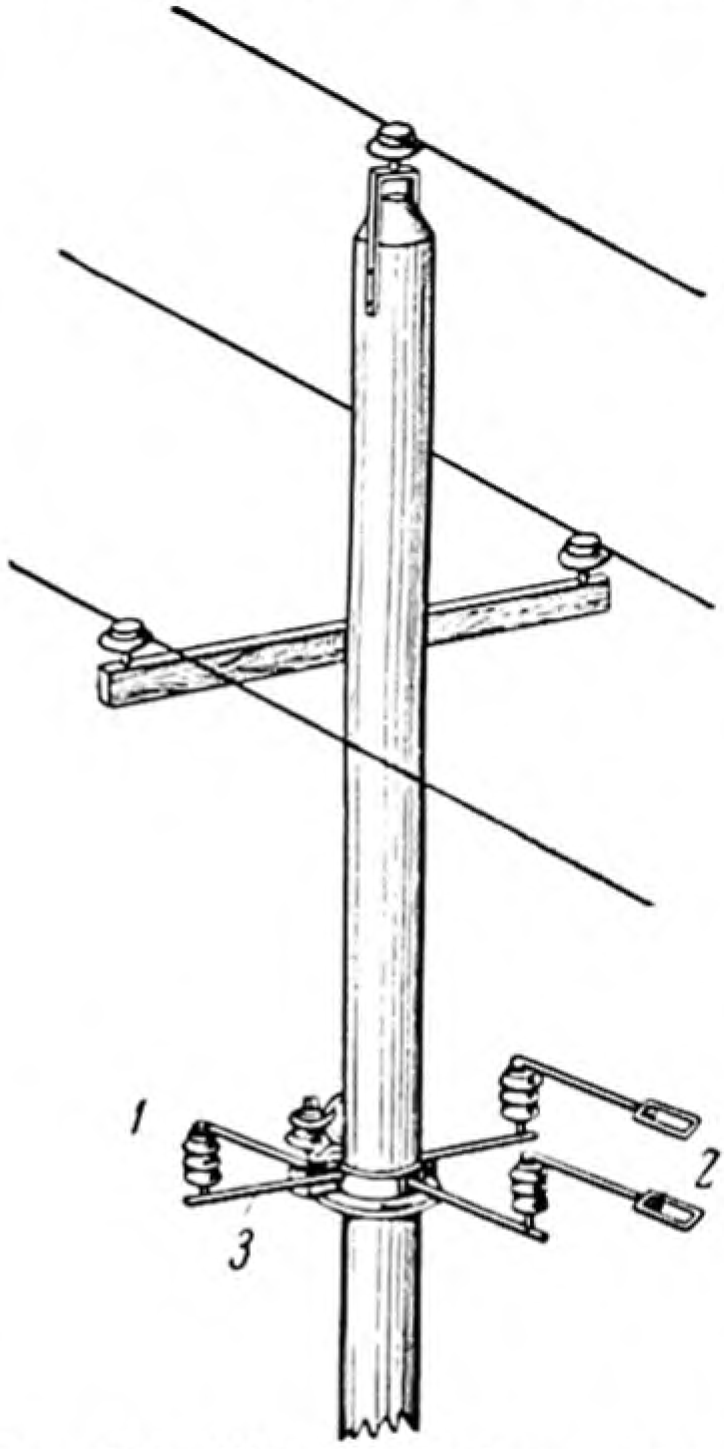


Fig. 336. ШД-10 insulators secured to disconnecting device collar:
1—ШД-10 pin-type insulator; *2*—finger contact; *3*—cantilever bracket

end the telescopic tube has a socket for seating on an insulating stick. The upper clamp has a right-hand thread, the lower contact clamp, a left-hand thread. A p.v.c. jacket is slipped on the lower tube of the telescopic link for making connection to the middle (upper) phase conductor.

Telescopic link units for the lower phase conductors are 2.2 metres long. A telescopic link unit will have a maximum weight of 4.5 kg.

Branch lines are usually connected by a crew of two. One of them, in charge of the work, should be an electrician of not lower

than Group IV rating with not less than 3 years of field experience as a linesman, and the other a linesman of not lower than Group III rating, with practical training in making connections between live main and tee-off lines.

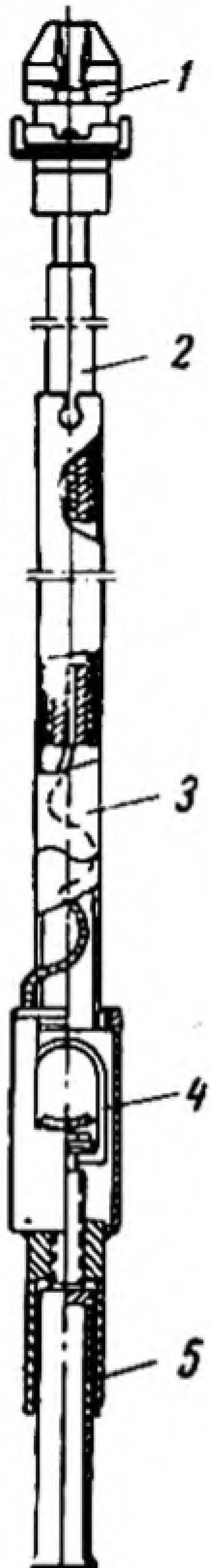


Fig. 337. Telescopic link fitted with upper and lower contact clamps:

1—upper clamp; 2—upper tube; 3—lower tube; 4—lower clamp; 5—socket

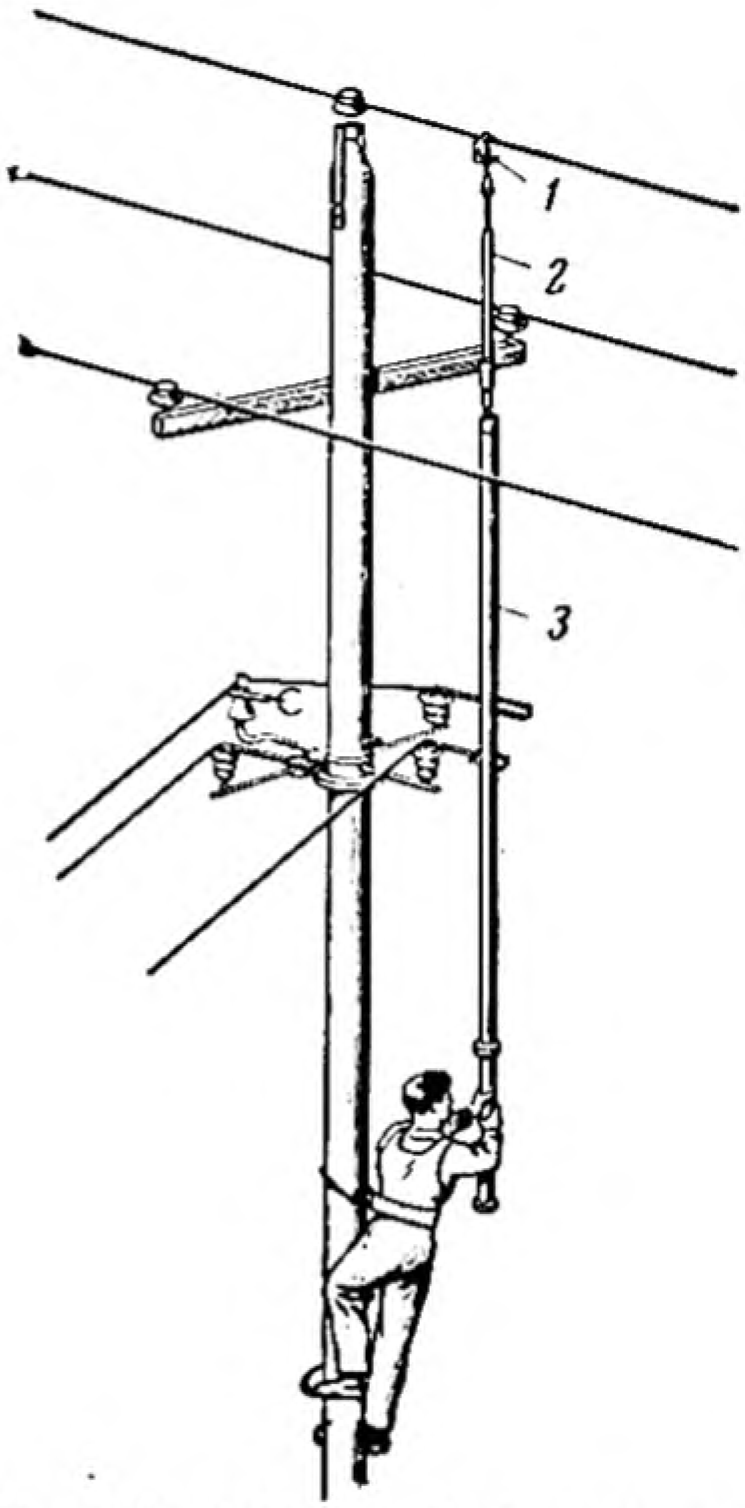


Fig. 338. Position of telescopic link mounted on the insulating stick and prior to securing the upper contact clamp to the main line conductor:

1—upper contact clamp; 2—telescopic link; 3—insulating stick

With the signed job-task sheet on hand, the crew checks their equipment and tools, get the location ready for work, the leading hand in charge of the work puts on his climbing irons and safety belt, climbs 2 metres up

the pole, and buckles his safety belt to the pole. The other linesman hands him an insulating stick with which the man on the pole measures off 2 metres from the lower cross-arm and mounts a pole collar at that level (Fig. 338).

Now the conductors to be strung between the terminal pole of the branch line and an intermediate support of the 6-kv main line (which makes a span of 15 to 20 metres) are clamped in the caps of ШД-10 insulators.

The attached conductors and insulators are then lifted in turn on the pole and fixed on the pole collar by means of the cantilever

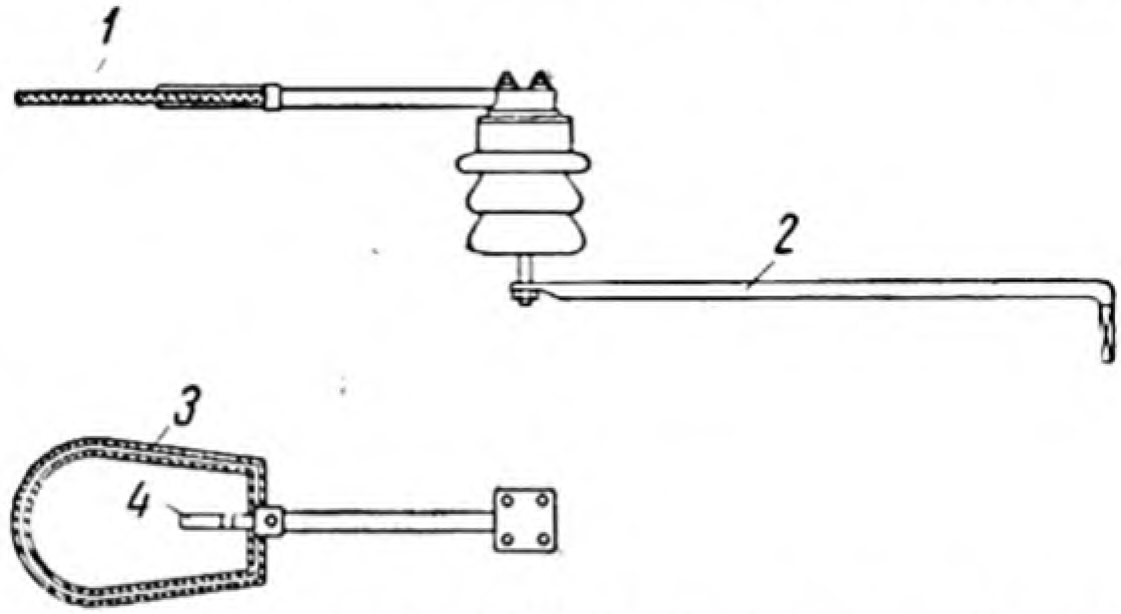


Fig. 339. General view of ШД-10 insulator complete with cantilever bracket and finger contact:
1—rubber sheath; 2—cantilever bracket; 3—guide ring; 4—finger contact

brackets so that the finger contacts fall in line with the respective main line conductors (Fig. 339). The conductors are now strung between the intermediate support of the main line and the tee-off line terminal pole.

The insulating stick is now lifted with its head-end up and with a telescopic link (in fully retracted position) inserted into its head.

The telescopic links are clamped to the conductors as follows:

(a) The telescopic link fixed on the insulating stick is passed through the guide ring and lifted level with the respective main line conductor, holding the stick in the vertical position (Fig. 340).

(b) The main line conductor is engaged with the upper clamp of the telescopic link, and the stick is turned clockwise to tighten the clamp on the conductor.

(c) The stick is lowered to extend the telescopic link just far enough to allow the lower clamp to slip over the contact finger on the collar bracket, and is turned counterclockwise, so that the contact finger is snugly fixed in the lower clamp (Fig. 340).

(d) The head of the stick is withdrawn from the socket of the telescopic link, and the stick is lowered to the ground.

The telescopic links should be connected in the following order: first comes the outer link on the branch-line side, then the middle link, and finally the other outer link.

The procedure for disconnecting a branch line is as follows. The crew get the location ready for work and inspect the tools, the leading hand climbs the pole, lifts the insulating stick, makes its head enter the socket of one of the links, turns the stick clockwise as far as it will go to unscrew the lower clamp, and then slips the link off the finger contact.

The stick next is pushed further up through the guide ring to retract the telescopic link fully and is then turned counterclockwise to unscrew the upper clamp which can now be detached from the line conductor, and the stick and telescopic link lowered through the guide ring, keeping the stick vertical all the time. When the stick is lowered far enough out of the guide ring, the telescopic link is taken off the stick head and lowered to the ground on a rope. The links are removed one after another in the reverse order of installation.

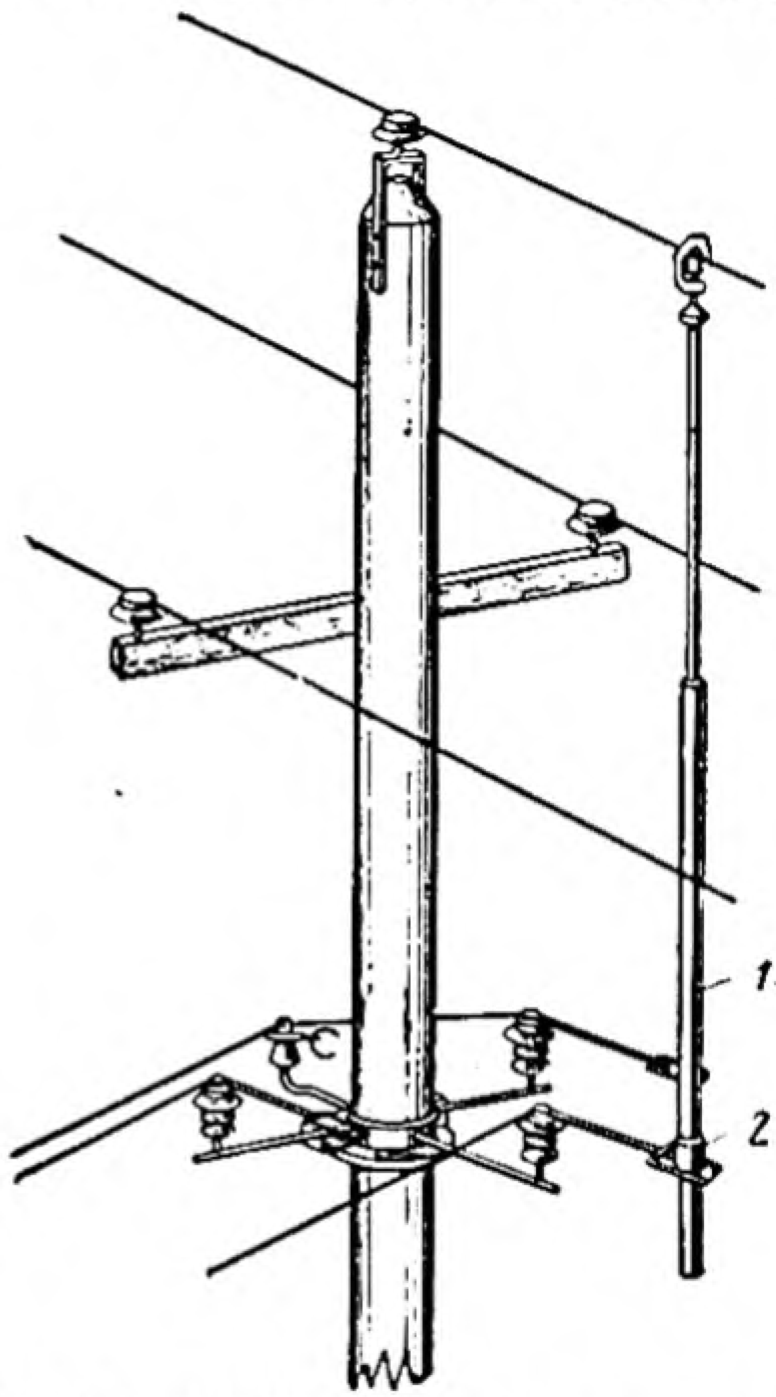


Fig. 340. Lower clamp of telescopic link secured on disconnecting-device finger contact:

1—telescopic link; 2—lower contact clamp

After all the telescopic links have been removed, the charge remaining on the tee-off line conductors should be discharged to earth. To do this, a flexible conductor attached to the insulated stick and connected to earth is brought into contact with the tee-off line conductors.

Cutting-off of a hot temporary tee-off from a 6-kv main line. This is done according to the instructions drawn up for this job and on only aluminium conductors in sizes not greater than 95 sq mm, using a special cutter mounted on a "hot" stick.

This hot-stick mounted cutter which is designed to sever hot branch lines phase by phase consists of an insulated stick (Fig. 341) and a cutter (Fig. 342). The insulated stick is made up of a head, an insulating body, and a grip. The head has a steel member which fits into

the cutter sleeve to lock it on the stick and to drive in and out the screw drive of the cutter.

The insulating body of the stick is made up of a three-piece ШР-35 bakelised tube coupled to a two-piece ШР-35 bakelised tube by an aluminium coupling. The bakelised-paper tubes are 35 mm in diameter. The weight of this insulated stick is 4 kg.

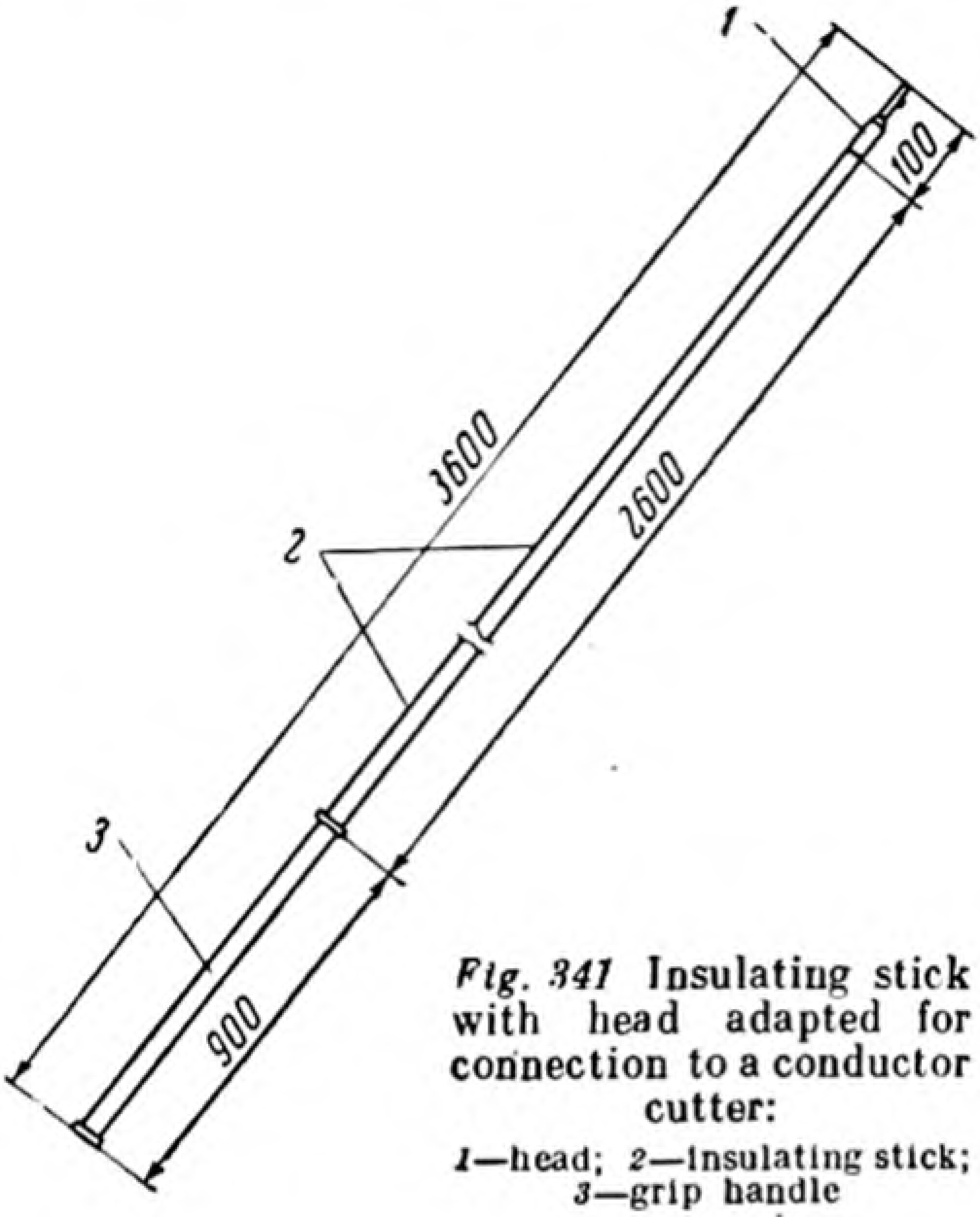


Fig. 341 Insulating stick with head adapted for connection to a conductor cutter:
1—head; *2*—insulating stick; *3*—grip handle

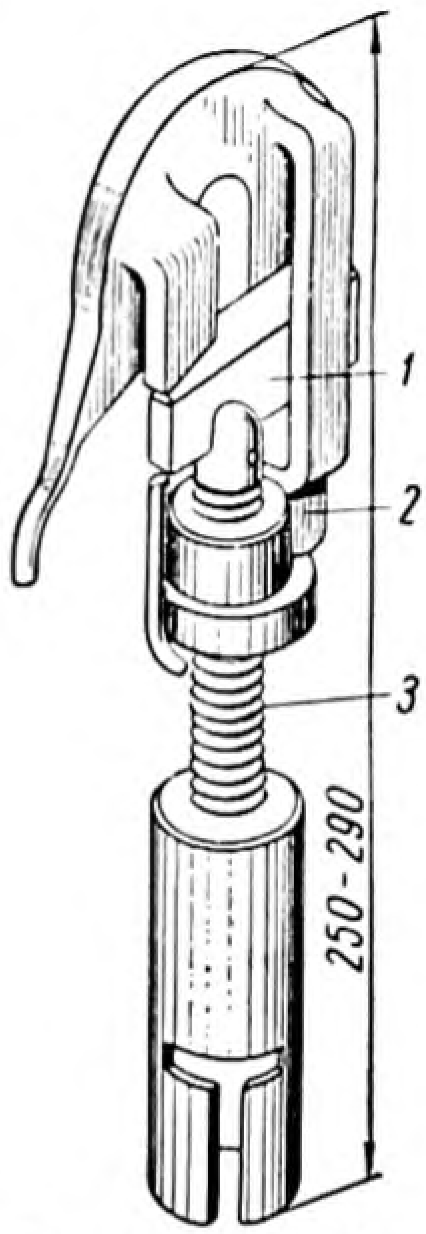


Fig. 342. Conductor cutter

The cutter proper (Fig. 342) consists of a steel head which engages the conductor to be cut, a drive screw *3*, a connecting steel bushing *2* which feeds the knife blade in the vertical direction and connects the cutter unit to the insulated stick, and a steel blade *1*. Such a cutter weighs 1 kg.

The head is coated with a 1-mm layer of a compound made by mixing p.v.c. and ethylene dichloride.

The linesman, assigned the cutting job, gets his tools and safety aids ready, puts on his climbing irons and safety belt, climbs the pole within not less than 2 metres of the lowest conductor on the side opposite the conductor to be cut, and buckles his safety belt to the pole. The 2-metre distance should be marked on the insulated stick. The other man of the crew then lifts the cutter to the man on the pole,

stands on the side opposite the conductor to be cut and watches to see that the linesman on the pole does the work properly.

The linesman on the pole makes sure that the cutter is reliably fastened on the insulated stick by the locator pin, checks to see that the insulators and conductors are made fast to the line support, puts on his safety rubber gloves and goggles, engages one of the lower conductors on the branch line with the cutter head within 100 mm of the insulator, and turns the stick clockwise. This lifts the cutter knife and severs the conductor.

The second and third conductors are cut in the same manner. The general sequence is to cut the lowest conductor, then the middle conductor, and, finally, the topmost conductor (Fig. 343).

Fig 343. Cutting upper conductor of temporary tee-off line

After the three conductors of the branch line have been cut, the linesman descends from the pole, signs his job-task sheet to confirm that the job has been done, and hands over the keys to the padlocks of the line disconnecting switches to the user (or users) of the severed tee-off line.

CHAPTER 16

ACCIDENT PREVENTION IN OPERATION AND MAINTENANCE OF POWER SYSTEM EQUIPMENT

89. General

Soviet codes class as "operating" those electrical installations which are alive fully or in part, or to which the voltage may be applied at any instant. Work on operating electrical installations is permitted only for persons over 17 years of age who have been trained in the rules of safety in operation and maintenance of electrical equipment, successfully passed an examination before a qualification board, and been issued a safety qualification certificate. In the U.S.S.R. five safety rating groups exist. Persons of Group I safety rating should never be allowed to enter an operating installation alone. Higher safety ratings are given to persons with firm knowledge of safety rules, skilled in safe performance of their jobs in an operating installation, familiar with the circuitry and equipment of the sections they are in charge of, and able to render first aid to a victim of electric shock.

Persons working on operating electrical equipment should be given periodic medical check-ups every two years.

90. Technical and Organisational Measures for Ensuring Safety

In the Soviet Union it is usual to class all safety measures into technical and organisational. Among the technical measures which ensure safety to personnel are:

(1) disconnection of equipment from service;
(2) placing of temporary guards and warning notices;
(3) no-voltage tests;
(4) attachment of temporary safety-earthing sets.

Disconnection of equipment from service. All current-carrying parts on which work is to be performed should be disconnected from the line. This also applies to all current-carrying parts which personnel may accidentally touch or approach closer than the following distances:

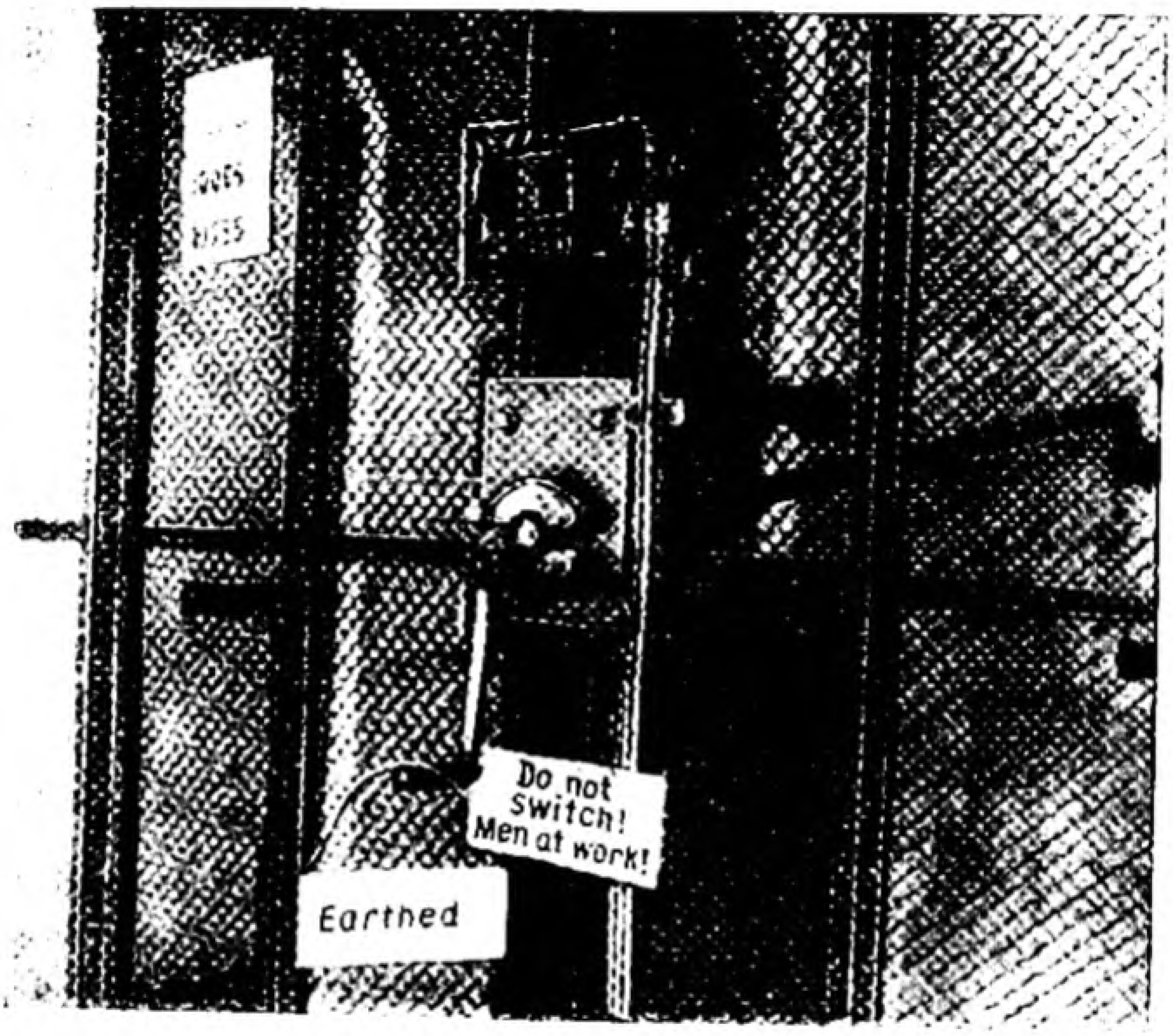


Fig. 344. View of a 10-kv substation at a cell switched out for repair (isolator provided with ПЧ-50 operating mechanism)

(a) 0.7 metre for parts at voltages up to 15 kv inclusive;

(b) 1 metre for parts at voltages from over 15 kv to 35 kv inclusive;

(c) 1.5 metres for installations with voltages from over 35 kv to 110 kv inclusive;

(d) 2 metres for 154 kv;

(e) 3 metres for 220 kv;

(f) 5 metres for 400 kv.

This should be done so that disconnected equipment will be isolated from live plant on all sides and a visible break provided on each side. No work shall be allowed on equipment cleared merely by opening circuit breakers.

Guards and warning notices. "Do Not Switch!—Men at Work!" notices should be hung on the operating mechanisms of all circuit

breakers and isolators, as well as on all control keys with which the voltage may be applied to the equipment where men work (Figs 344 and 345).

In indoor substations "Stop!—High Voltage!" notices should be hung on the wire-netting or solid walls of the compartments or cells

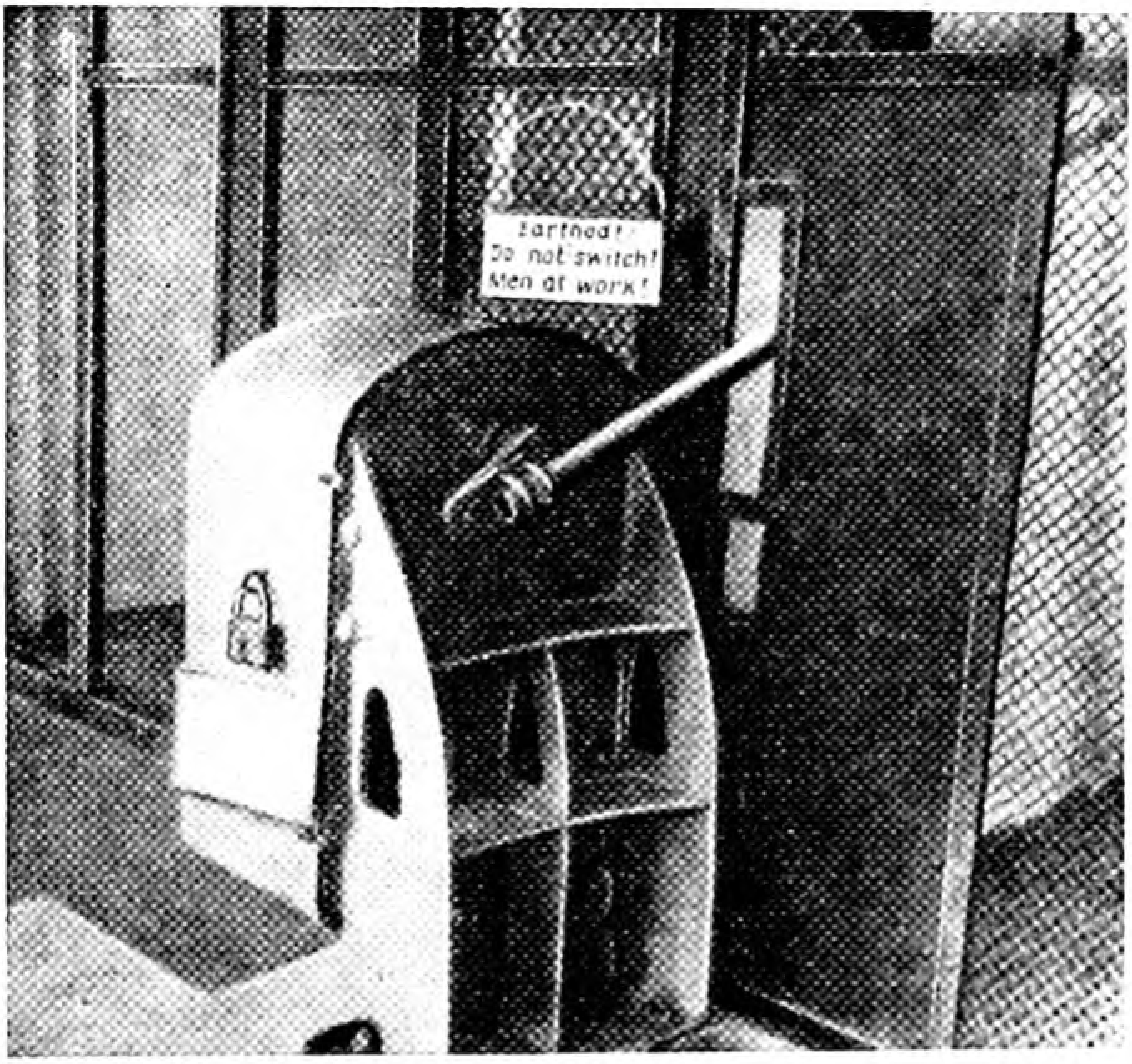


Fig. 345. View of a 10-kv substation at a cell switched out for repair (isolator provided with a motor-driven operating mechanism)

next to and opposite the location where the work is to be performed. If these cells have no barriers, portable guards bearing the words "Stop!—High Voltage!" should be put up near them and at all points where repair personnel is not allowed to enter.

In outdoor substations the work location is fenced off with a rope from which a "Stop!—High Voltage!" notice is hung. When work is carried out on top of a common structure, the work location is marked off by "Stop—High Voltage!" notices to block the way to the neighbouring live sections. On the ground, "Don't climb!—Dangerous to Life!" notices must be attached to the structures next to the one used by personnel. On the structures which the crew is allowed to climb to reach the work location, "Climb Here!" notices should be hung.

No-voltage test. That the disconnected equipment is dead is ascertained by operators after the necessary warning signs and temporary barriers and guards have been put up and temporary safety-earthing sets have been attached to the earthing systems. Prior to a test, the high-voltage indicator used for the purpose (Fig. 346) must be checked. For this, the end of the indicator is brought close to a nearby live part.

Fig. 346. High-voltage indicator

Disconnected equipment should be tested for no-voltage across all terminals, and each circuit breaker across its six terminals.

Temporary safety-earthing sets. Temporary safety-earthing sets are attached to earth and short all three phases (Figs 347, 348, 349) of the equipment to be installed or repaired.

Temporary safety-earthing sets may only be attached and removed by two men working together, one of them with a safety rating of not below Group IV, and the other not below Group III. First an earthing set is applied to earth and then is, by means of an insulating stick, clamped to the current-carrying parts

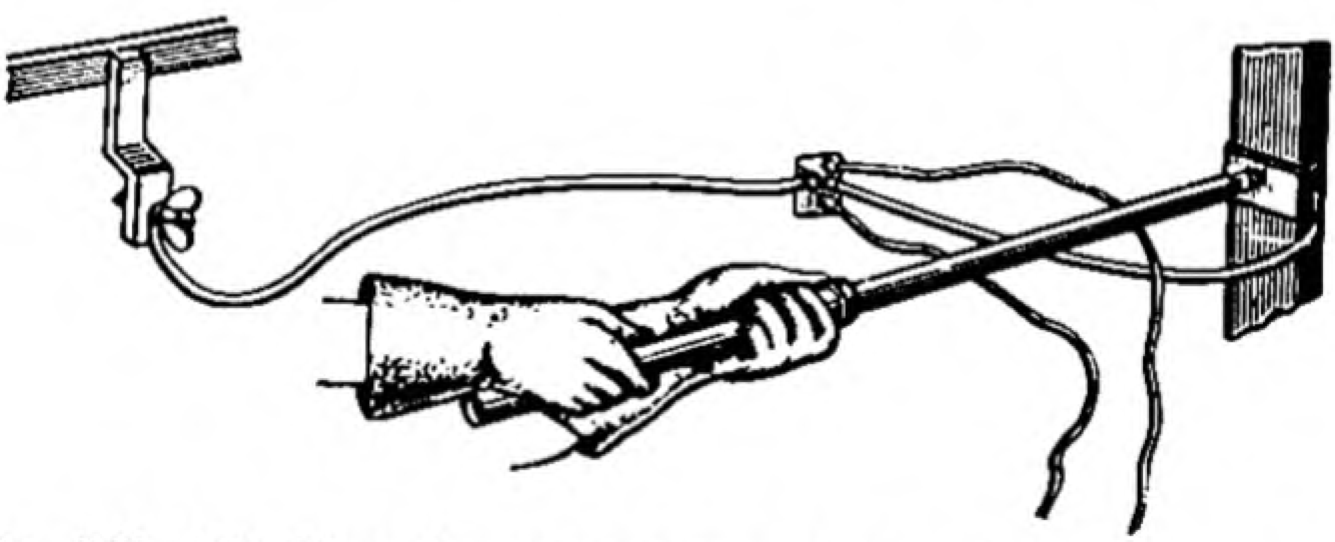


Fig. 347. Attaching the temporary safety-earthing set to current-conducting parts with the aid of an insulating stick

of all three phases, with rubber gloves on (Fig. 350). The power and instrument transformers on the L.V. side should also be disconnected, as there exists the danger of reverse transformation of the low into a high voltage.

The organisational measures by which safety to personnel is ensured include: use of written and signed job-task sheets, permits to

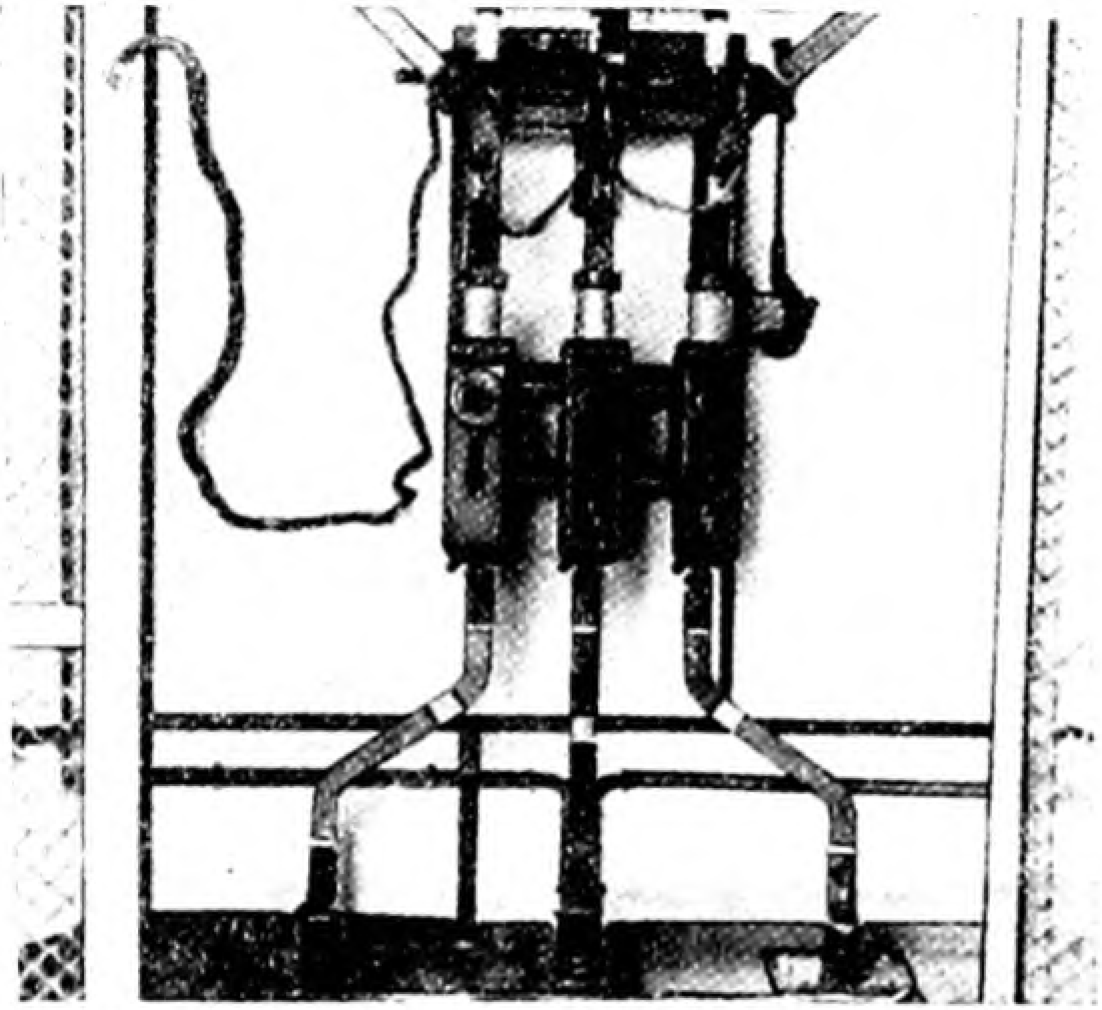


Fig. 348. View of a switchgear cell with the safety-earthing set attached and circuit breaker prepared for performance of work

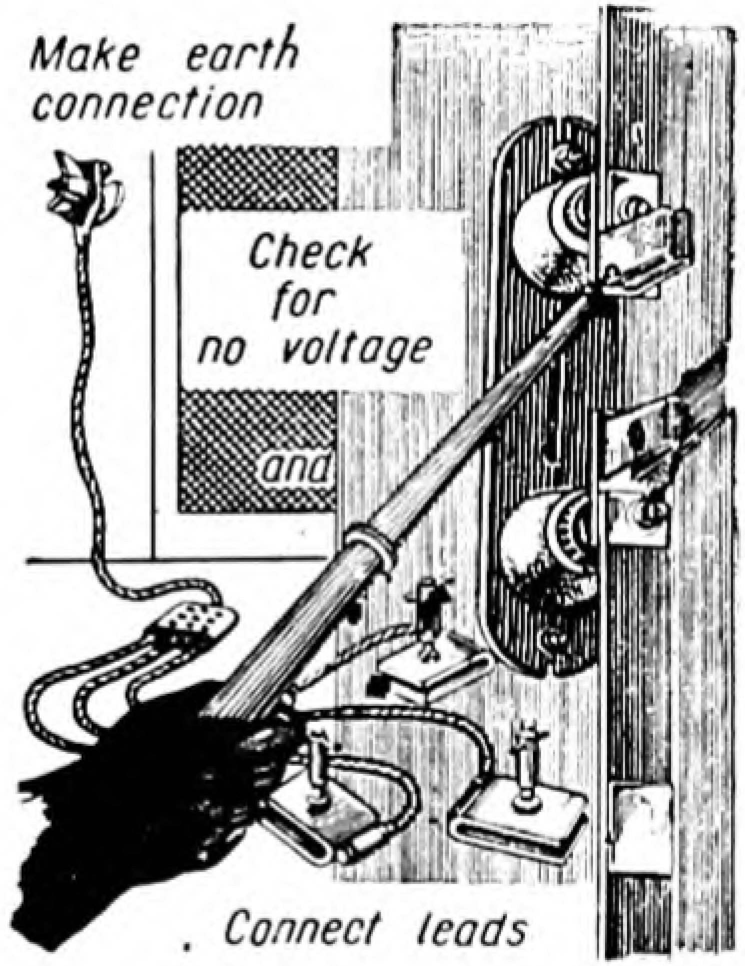


Fig. 349. Principal protective aids

work on electrical equipment, supervision during work, and signed clearances and cancellations.

Job-task sheet. Job-task sheets are written instructions for the performance of any work on electrical equipment. They fix the place, time, and conditions of work, the set-up of the crew and the person in charge of safety.

Fig. 350. Nonconducting rubber gloves

Job-task sheet for work on electrical equipment

Name of organisation ____________________

____

Job-Task Sheet No. ____________

To the person in charge of the work, watcher

____

(name, initials, safety rating)

Job assigned ____________________

(state installation, circuit, extent of work to be done)

____

Conditions of work ____________________

(with partial or full disconnection from service

____

on hot equipment, with temporary safety-earthing, where and why)

Special instructions ____________________

____

Begin work at: ______ hour ______ min ______ day ______ month ______ year

Supervisor ____________________

(name, initials, safety rating)

Job-task sheet issued ______ day ______ month ______ year by ____________

____

(signature)

Crew set-up: ____________ men ____________

____

____

(names, initials, safety ratings)

Signed by ____________

Supervisor
(or person issuing job-task sheet)

Necessary safety measures taken:

______ hour ______ min ______ day ______ month

______ year

Signed by ____________
(operator in charge)

Safety of work $\frac{\text{in location}}{\text{on apparatus}}$ checked: ______ hour

______ min ______ day ______ month ______ year

Signed by ____________
(supervisor)

Changes in Crew

Put on crew (names, initials, safety ratings)	Withdrawn from crew (names, initials, safety ratings)	Date and time	Permission granted by

Daily renewals of the permit to work, completion of work, transfers to other jobs

<table>
<tr><th>Location or apparatus</th><th colspan="3">Permit to work</th><th colspan="3">Clearance</th></tr>
<tr><td></td><td colspan="3">Necessary safety measures taken. Crew acquainted with conditions for performance of work and with safety measures taken</td><td colspan="3">Crew withdrawn, job-task sheet turned in</td></tr>
<tr><td></td><td colspan="6">Remaining alive are ____________</td></tr>
<tr><td></td><td colspan="6">(state what current-carrying parts are left alive in the bus system repaired)</td></tr>
<tr><td></td><td>Date, time</td><td>Permission given by (signature)</td><td>Leading hand in charge of the work (signature)</td><td>Date, time</td><td>Leading hand in charge of the work (signature)</td><td>Operator in charge (signature)</td></tr>
<tr><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
</table>

The work covered by job-task sheet fully completed: ________________

hour________ min __________ day ________ month________ year

Signed by ________________________________

(supervisor)

Apparatus and location accepted, job-task sheet turned in:

________hour ________ min__________ day__________ month__________

year

Signed by________________

(Operator in charge)________________________________

Note: No cross-outs are permitted in a job-task sheet. Enter in the operator's log all switchings and temporary-earthing sets used (state their numbers).

Admission to the electrical equipment or location to be repaired. Before any work may commence, the operator accompanied by the supervisor and the leading hand in charge of the work make sure once again that the requisite safety measures have been taken, and permit the crew to enter the switchgear premises. The operator leads the way to the location and touches the disconnected equipment for the crew to see that the necessary disconnection has been performed.

The crew is also shown the adjacent equipment left alive in the substation. All live parts should be fenced off.

Supervision during work on electrical equipment. During intervals and breaks in the course of a work-day, the entire crew must be escorted out of the switchgear building or switchyard, with the job-task sheet left in the hands of the leading hand in charge of the work. After the interval or break, the crew may be escorted to the work location by its leader in the absence of the operator.

Completion of work on electrical equipment. At the end of the working hours, the location should be made tidy. The job-task sheet should be handed over to the operator. The next day the crew may resume work after going through all the same formalities.

When all the repair work is completed, the job-task sheet is cancelled (signed) by the supervisor, and the work location and keys are taken over by the operator in charge. After this, the equipment may be put back into operation.

91. Protective Aids Used in Electrical Installations

Protective aids include instruments and portable fixtures issued to personnel working on or near electrical equipment remaining "hot" in order to protect them against electric shock and arcs.

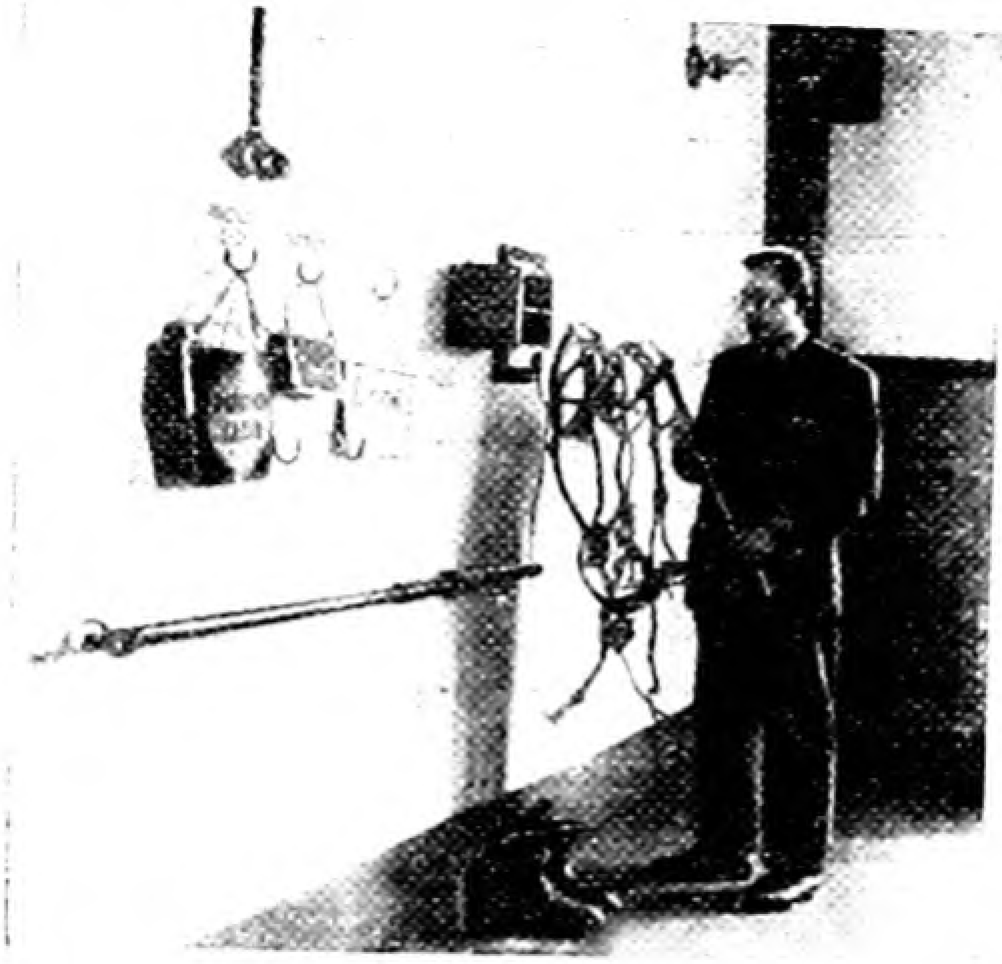


Fig. 351. Protective aids and appliances

More specifically, these are (Fig. 351):

(a) portable voltage indicators and clip-on ammeters;

(b) temporary safety-earthing sets, portable guards and warning notices;

(c) protective goggles, canvas gloves and gas masks for protection against arcs, fumes and mechanical injury;

(d) nonconducting (rubber) gloves (Fig. 350) and gauntlets, nonconducting (rubber) boots and rubbers (Fig. 352), insulating pallets (Fig. 353), nonconducting (rubber) mats (Fig. 354), "hot" sticks, and "live-line" tools with insulated handles.

The insulating pallet shown in Fig. 353 is used for voltages both up to 1,000 volts and higher.

Soviet codes for the use and testing of electrical protective aids require that newly-made insulating pallets should withstand a 40-kv test voltage for one minute.

Fig. 352. Nonconducting boots and rubbers

It is required that attended substations always have on hand a set of numbered temporary safety-earthing sets, assorted warning notices, portable temporary guards and voltage indicators.

Unattended switchgear installations for over 1,000 volts should be furnished with a "hot" stick, insulating pallet (or nonconducting rubber boots) and insulated fuse pullers. The other protective aids, such as rubber gloves, voltage indicators, goggles, warning notices, portable guards, shorting and earthing jumpers, and gas masks should be kept by the crews servicing the electrical installations.

The protective aids assigned to a given substation should be kept in a suitable room or place.

All protective aids should be tested before use for the first time and then at the intervals listed in Table 36. A protective aid should also be tested each time after some replacement or when there is doubt as to its fitness.

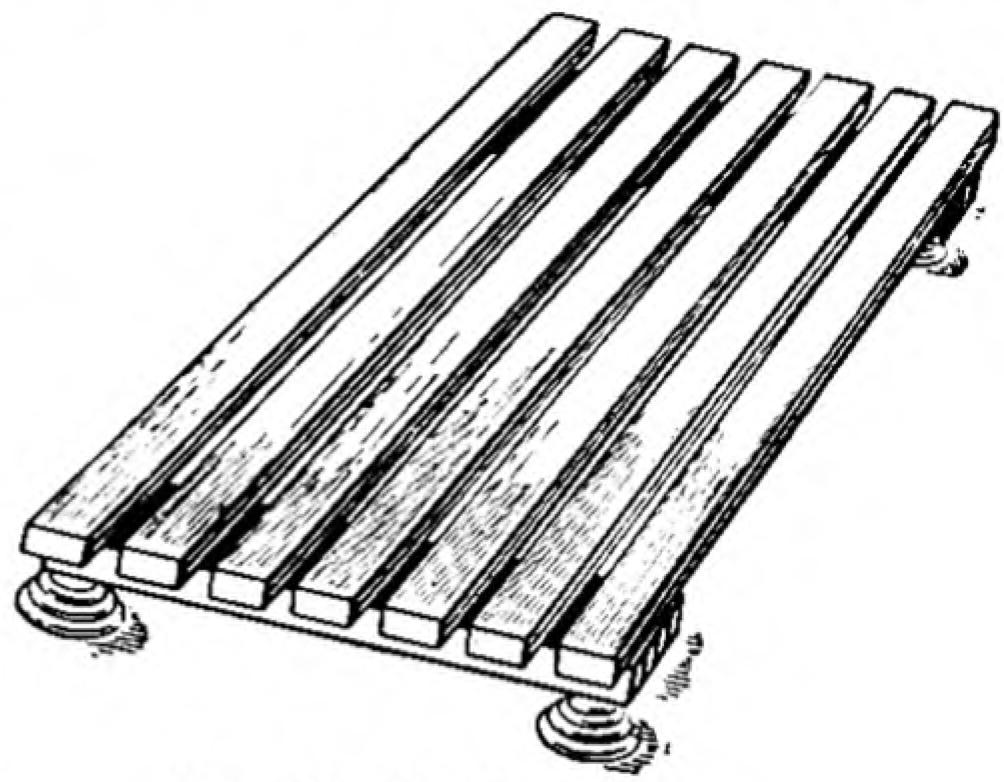


Fig. 353. Insulating pallet

Protective aids, both in use and in storage, are tested and checked for missing items at intervals of three months.

Protective aids may be given a proof voltage test by an authorised person and on a special device only.

Before use, a protective aid should be checked for overall condition, any external damage, and dirt on its surfaces. It is not permissible to use "hot" sticks and live-line fuse pullers which are covered with dust and bear signs of carbon and pencil marks. Rubber gloves, boots and rubbers should be free from frayed surfaces, cracks, blisters and any foreign inclusions. Defective protective aids should be immediately taken out of service.

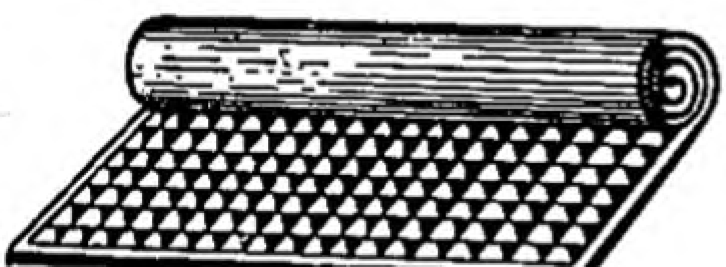


Fig. 354. Rubber mat

Protective aids should also be checked for the date of next inspection stamped on them, to make sure that it is not overdue. If it is, such aids must not be used.

Furthermore, before a "hot" stick puller or voltage indicator may be used, its stamped marking should be checked to see for what voltage it may be employed.

ШР-10 and ШР-35 hook sticks for indoor substations. ШР-10 and ШР-35 sticks are removable operating rods intended for manually closing and opening live isolators off load.

Their use should be limited to indoor substations with working voltages not higher than indicated on each stick.

Care must be taken not to injure the varnish coatings of the sticks in order to prevent the insulation from moistening.

Table 36

Standards and Test Periods Protective Aids

Protective aid	Switchgear voltage	Electric tests*		Leakage current, ma	Schedule of tests	Additional requirements
		test voltage	duration of test			
Insulated sticks	Up to 110 kv	Three times line voltage, but not less than 40 kv	5 min	—	Sticks of all types (other than hook sticks for unattended installations, and measuring stick)—once a year. Operating sticks for unattended installations—every two years. Measuring sticks, every six months. During measurement period, if kept by measuring crew, tested every 2 months.	Compression and tension tests of all sticks once after manufacture (other than measuring sticks) by 150 kg load; for sticks rated up to 10 kv and with porcelain inserts, by 80 kg load. Duration of each test, one minute.
Insulated sticks	110 kv and higher	Three times phase voltago	5 min			
Insulated sticks	35 kv and lower	Three times line voltage, but not less than 40 kv	5 min		In attended installations, every year. In unattended installations, every two years.	
Nonconducting rubber gloves	Above 1000 v	6 kv	1 min	7	Every 6 months	

Continued

Protective aid	Switchgear voltage	Electric tests		Leakage current, mA	Schedule of tests	Additional requirements
		test voltage	duration of test			
	Up to 1000 v	2.5 kv	1 min	2.5	Every 6 months	
Rubber boots	Any voltage	15 kv	1 min	7.5	Every 6 months	
Nonconducting rubbers	Up to 1000 v	3.5 kv	1 min	2	Every 6 months	
Nonconducting rubber mats	Above 1000 v	15 kv	Pulled at 2-3 cm/sec	15	Every 2 years	
	Up to 1000 ·	5 kv	Pulled at 2-3 cm/sec	2	Every 2 years	
Insulating pallets	For any voltage	40 kv	1 min	—	Every 3 years	Inspection instead of tests every 6 months
Linesman's tools with insulated handles	Up to 1000 v	3 kv	1 min	—	Every 6 months	
Voltage indicators	Up to 10 kv inclusive					
(a) indicator proper		20 kv	1 min	—	Every 6 months	
(b) holder		40 kv	5 min	—	Every 6 months	
Voltage indicators	Over 10 kv and up to 35 kv inclusive					
(a) indicator proper		20 kv	1 min	—		
(b) holder		105 kv	5 min	—		
Phasing tubes	6 kv	6 kv	1 min	1.7 to 2.4	Every 6 months	
	10 kv	10 kv	1 min	—	Every 6 months	
Clip-on ammeters	Up to 10 kv inclusive	40 kv	1 min	1.4 to 1.7	Once a year	

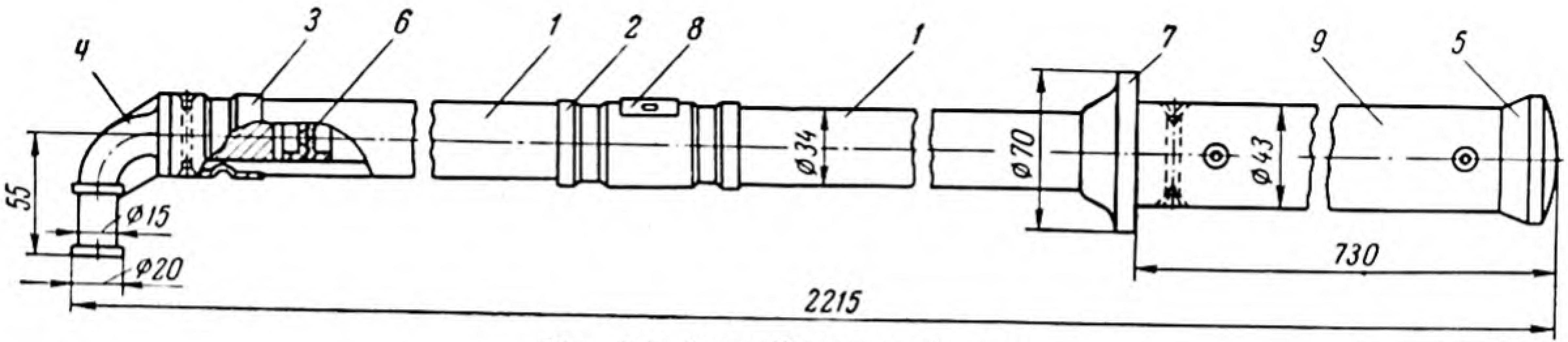


Fig. 355. Type ШР-10 hook stick

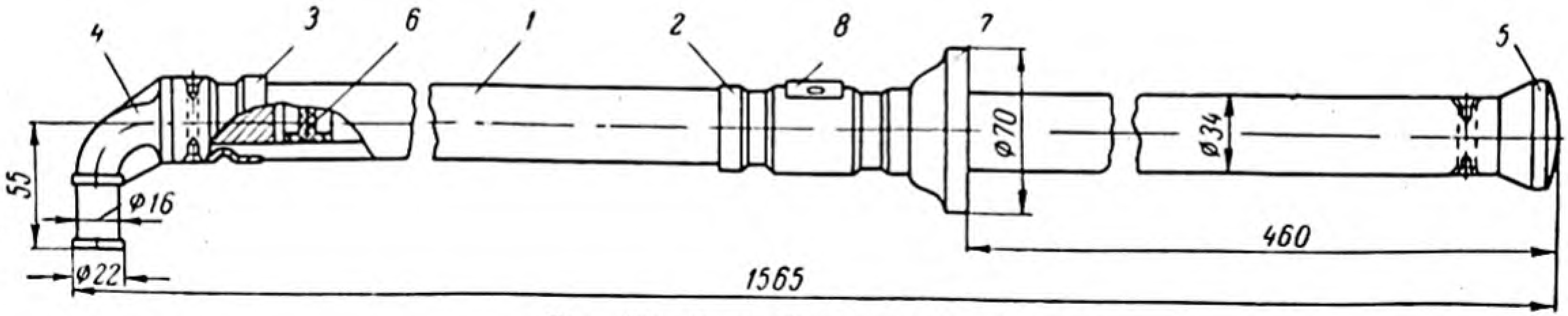


Fig. 356. Type ШР-35 hook stick

ШР-10 hook sticks are rated for a nominal voltage of 10 kv and a maximum voltage of 11.5 kv; ШР-35 hook sticks are rated for a nominal voltage of 35 kv and a maximum voltage of 40.5 kv.

A ШР-10 hook stick weighs 1.8 kg, and a ШР-35 hook stick, 2.5 kg. A ШР-10 hook stick (Fig. 355) consists of two bakelised-paper tubes *1* joined together by a steel coupling *2*. The latter is press-fitted over the ends of the tubes. This coupling carries the nameplate *8* of the stick. The working part of the stick is separated from its grip by a hand guard *7* at the coupling.

The bakelised tubes have plugs *6* at the ends and at the joint. These plugs protect the inside of the tubes from ingress of moisture.

A steel ferrule *3* press-fitted on the insulating end protects the tube insulation from mechanical injury in use.

Fig. 357. Stick used for attaching temporary earthing lead to overhead line conductor

A hook *4* is pressed into the tube and secured to it and the ferrule *3* by a pin. At the lower end of the grip a heel plug *5* is press-fitted into the tube and secured in place by a pin.

A ШР-35 hook stick (Fig. 356) consists of three bakelised-paper tubes. Two of these tubes *1* make up the insulating body of the stick and are joined together by a steel coupling *2*. The third tube of a larger diameter is press-fitted on the tube *1* and fixed to it with pins to serve as the grip. The grip has a hand guard *7*. In all other particulars ШР-35 hook sticks are identical with ШР-10 hook sticks.

Fig. 357 shows a stick used for attaching a temporary earthing lead to an overhead line conductor.

In indoor substations, outdoor substations, and for overhead lines, insulated sticks are handled while standing on an insulated surface (an insulated pallet or a rubber mat indoors or a safety platform outdoors). The man working with a stick should wear nonconducting rubber gloves, and, when working outdoors, also nonconducting rubber boots.

Live-line fuse pullers. The use of wooden fuse pullers is now being discontinued because their short length requires working from ordinary or step ladders in some cases. Furthermore, any accidental loosening of the grasp on the puller may lead to the fuse cartridge slipping out of the jaws and being damaged when it strikes the floor in the cell.

Present practice is to use more convenient metal tongs mounted on ordinary operating hook sticks (Fig. 358).

An operating hook stick is inserted in a slot *3* on the screw *4* and is secured there by turning a split ring *6* about the screw until their slots do not coincide.

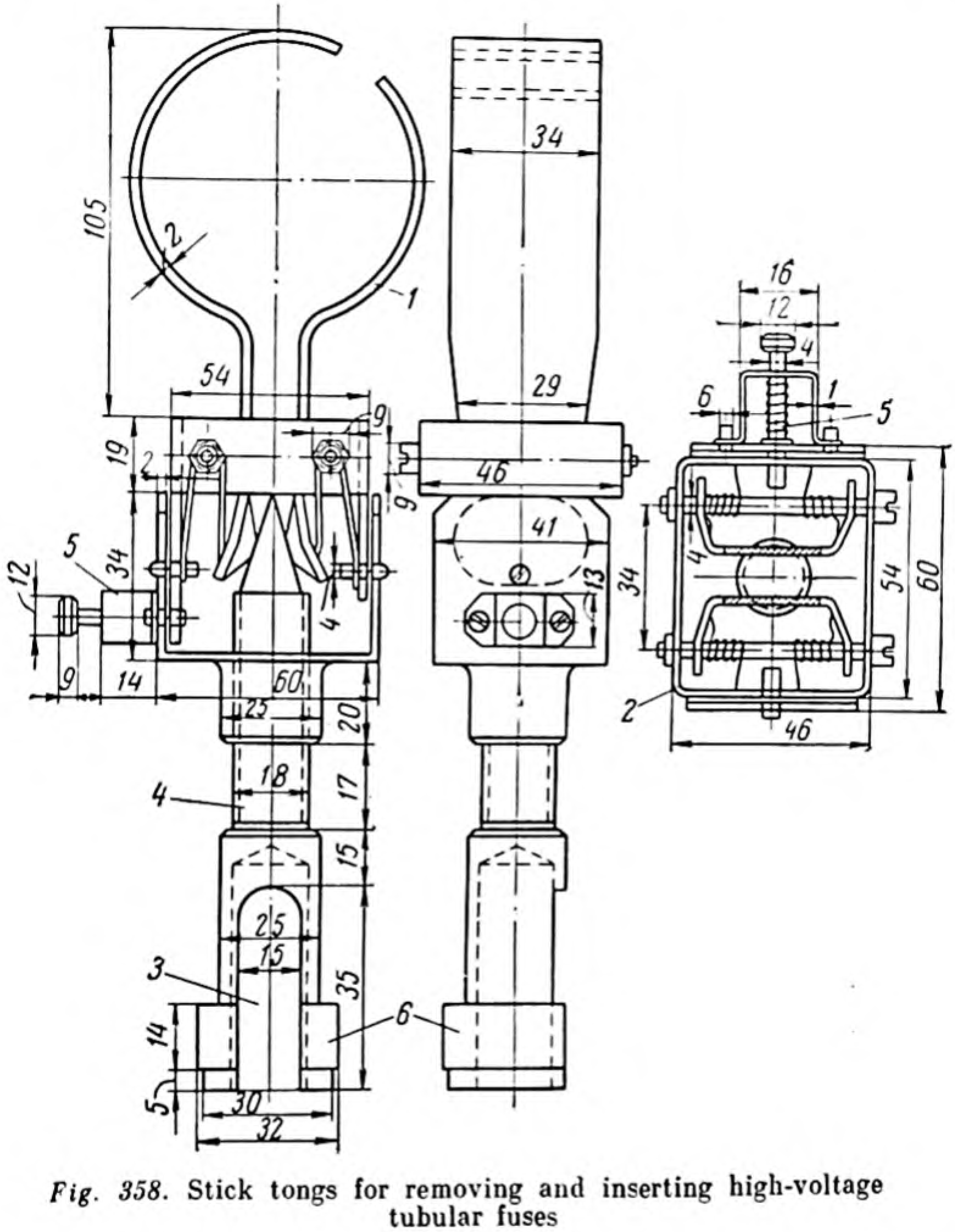


Fig. 358. Stick tongs for removing and inserting high-voltage tubular fuses

A fuse cartridge is engaged with jaws *1*. Turning the stick and, hence, the screw *4*, closes the jaws as a result of the pressure exerted by the conical end of the screw on the heels of the jaws.

With the fuse cartridge thus clamped, it can be either inserted in or removed from its holder.

The frame *2* of the clamping assembly has a spring-loaded stop *5* which permits the jaws to be set in three positions relative to the stick axis: one normal and two inclined positions. The stick making an angle with the floor makes it possible to hold the jaw vertical and obtain a positive grip on the fuse cartridge when it is located at some height from the ground.

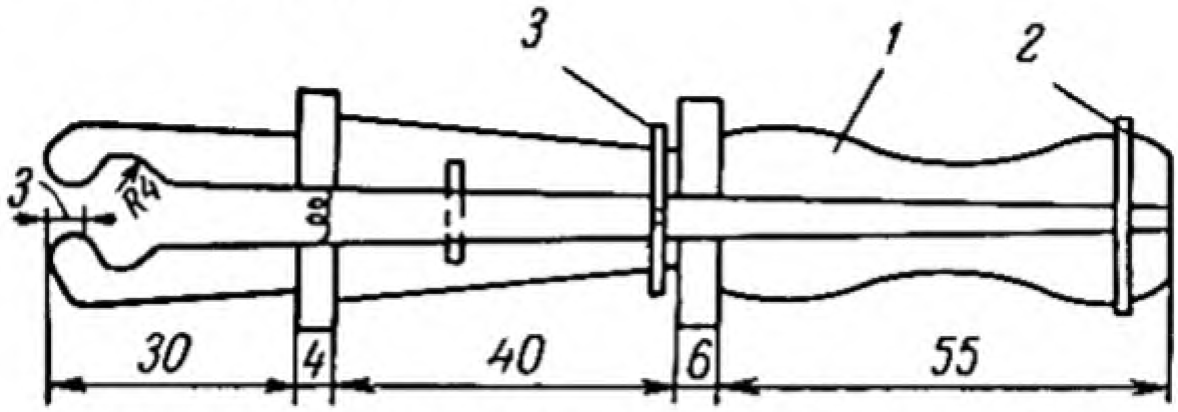


Fig. 359. Puller for replacing ППТ high-voltage fuses

To prevent the fuse cartridge from slipping in the jaws, they are lined with strips of felt on the inside.

A puller for ППТ high-voltage fuses. ППТ fuses are replaced by means of a puller shown in Fig. 359. It consists of two parts *1* identical in shape and made from an insulating material (such as p. v. c.) and joined together by fixed steel split ring *2*. Another, movable ring *3* when shifted over the tapered part of the device, causes both halves to close fully.

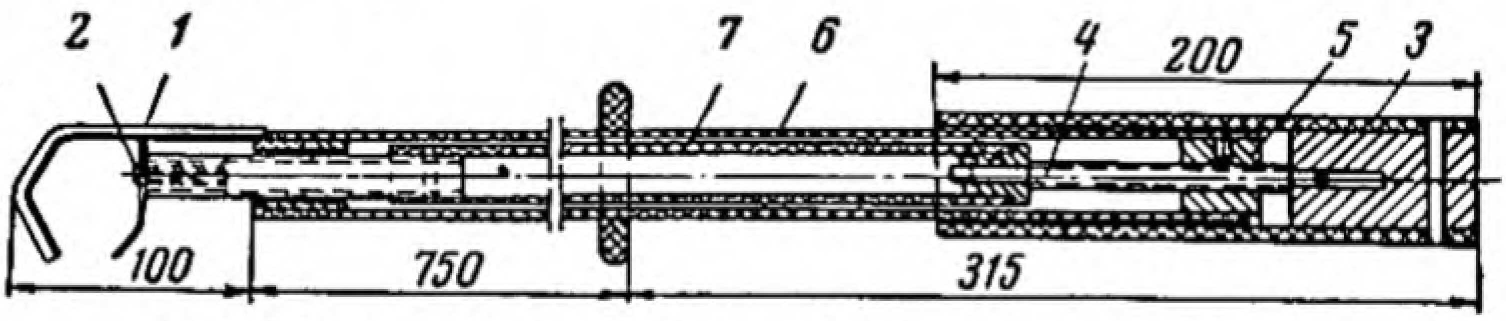


Fig. 360. Puller for replacing ПКТ high-voltage fuses

This puller is simple to use. With its jaws opened, it is slipped over a fuse, the movable ring is pushed up the taper (to left in Fig. 359) until the fuse is clamped between both halves. The fuse can now be pulled out of its holder. This puller ensures a firm grip on the fuse.

A puller for ПКТ high-voltage fuses. This puller has been devised to replace ПКТ fuses in 6-kv instrument transformer circuits while they remain hot (Fig. 360). This puller, mounted on an insulated stick, consists of a fixed jaw *1* and a moving jaw *2*. The fuse is engaged by the jaws, and the handle *3* is turned. This drives the screw *4* having a trapezoidal thread into the nut *5* which is secured in a bakelised-paper tube *6*. The inner bakelised-paper tube *7*, made fast to the screw, causes the movable jaw to move forward and thus clamp the fuse.

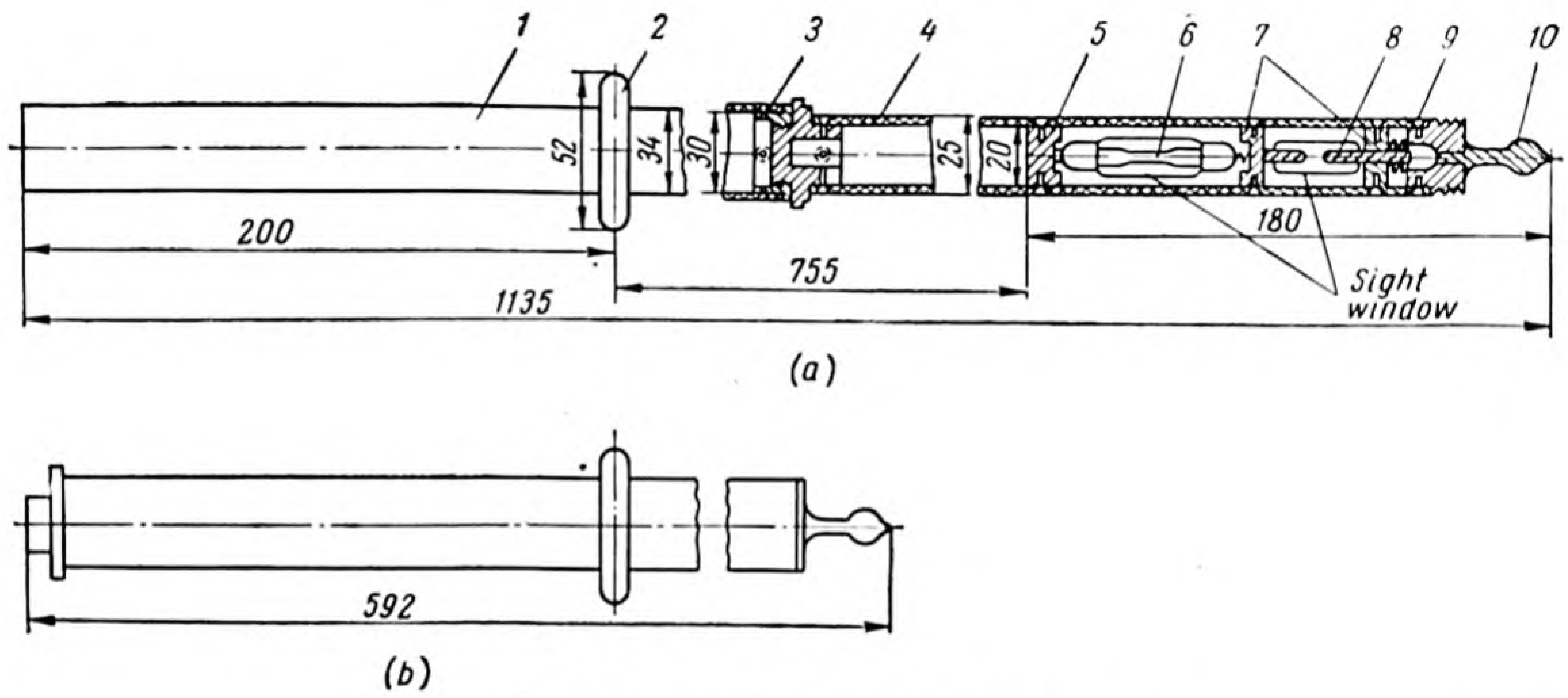


Fig. 361. 15-35-kv voltage indicator:

a—assembled for use: *1*—bakelised-paper grip; *2*—hand guard ring; *3*—nut and screw of steel coupler; *4*—bakelised-paper tube of indicator; *5*—lower contact-stop for lamp; *6*—neon lamp; *7*—spark-gap electrodes (brass); *8*—adjustable electrode (brass); *9*—steel set screw for electrode; *10*—brass probe; *b*—view in telescoped condition

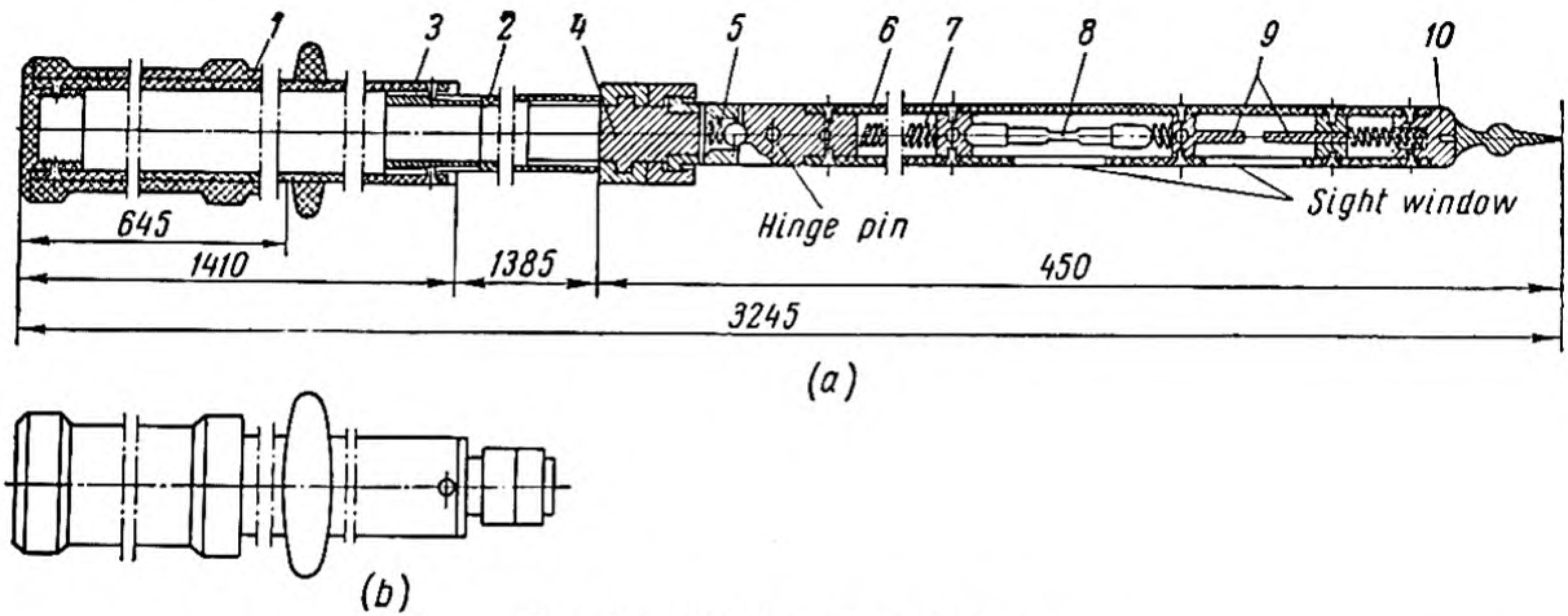


Fig. 362. **60-110-kv voltage indicator:**

a—assembled for use: *1*—bakelised-paper grip 35/30 mm; *2*—intermediate bakelised-paper tube 25/20 mm; *3*, *4*—aluminium couplings, *5*—inclination lock (steel); *6*—bakelised-paper tube of indicator, 18 mm O.D., 12 mm I.D.; *7*—steel contact spring; *8*—neon lamp; *9*—brass spark-gap electrodes; *10*—brass probe; *b*—view in telescoped condition

The fuse can then be pulled out of its holder clips for replacement. The jaws of this puller are made of an insulating material to thereby ensure greater safety to personnel.

Voltage indicators for voltages over 12 kv. УВН-1 voltage indicators commercially available in the U.S.S.R. at present are rated for 12 kv. They may, however, be used on higher voltage when mounted on an operating stick.

A few improvements in the УВН-1 indicator, substitution of a spark-gap for the capacitors of the neon lamp, and use of lighter, but sufficiently strong insulated tubes, have made available two new models of this voltage indicator, namely for 15-35 kv and 60-110 kv service.

The 15-35 kv voltage indicator (Fig. 361) consists essentially of a probe *10* to touch live parts, spark gap *7* with adjustable rod electrode *8*; neon lamp *6*, bakelised-paper tube *4*, and grip *1* fitted with a hand guard ring *2*.

In transit, the grip and the bakelised-paper tube can be telescoped to reduce the overall length and protect the neon lamp from damage

The 60-110 kv voltage indicator is diagrammatically shown in Fig. 362. It incorporates an intermediate bakelised-paper tube *2*. To make the glow of the neon lamp brighter, the latter is connected to the coupling *4* by means of a spring *7*.

In order that the neon lamp can be watched conveniently, the indicator tube proper can be turned into any of two fixed positions to make an angle of 45 degrees or of 90 degrees with the tube.

For carrying, the indicator is taken apart and the three sections slip one into another and can be screwed together.

Addition of one more intermediate insulated member makes the above indicator suitable for voltages from 150 to 220 kv.

The glow of the neon lamp in these indicators depends upon the spark gap interval, which should be adjusted so that the neon lamp will begin to glow at 25 per cent of rated voltage.

92. First Aid in Cases of Electric Shock

According to the Safety Code, personnel operating and servicing electrical equipment should be systematically instructed on the hazards of electric current, and methods of first aid, trained in breaking a shock victim's contact with the source of current and in the application of artificial respiration.

Efficient first aid to a victim of electric shock greatly depends upon fast action, resourcefulness, and the skill to render it. This skill is acquired through practical exercises.

If a victim is still in contact with live equipment, the very first thing to do is to de-energise this equipment.

To break the victim's contact with live parts at voltages up to 1,000 volts, dry clothing, a dry rope, dry board or any other dry non-conductor must be used.

When freeing a victim from contact with live equipment at above 1,000 volts, the following must be borne in mind:

(a) if the victim is aloft, measures must be taken to prevent him from falling or to make his fall safe;

(b) if the victim is in contact with one conductor, it is frequently sufficient to earth only this same conductor;

Fig. 363. First method of artificial respiration (air forced out of lungs)

(c) the wire used to short or earth the conductor must first be connected to earth and then thrown across the line conductors to be earthed;

(d) if it has a high capacitance, an opened line may retain a charge dangerous to life, and only reliable earthing will make it safe.

Methods of artificial respiration. Artificial respiration may only be applied when the patient does not breathe or breathes with difficulty (at delayed intervals, or convulsively as if sobbing), and also when breathing gradually grows feeble.

In order to be effective, artificial respiration must be applied immediately after the patient has been freed from contact with the live circuit and continued until normal breathing has been restored or until the onset of rigor mortis.

Before artificial respiration may be applied, any tight clothing which may interfere with the patient's breathing must be loosened, his collar made loose, the muffler removed, all foreign matter wiped out of his mouth, and the mouth opened.

If the man rendering the aid is alone, the prone pressure method, the simplest and easiest of all, is recommended (Fig. 363).

(1) Lay the patient on his belly, one arm extended directly forward, the other arm bent at the elbow and with the face turned sideward and resting on the hand or forearm.

(2) Kneel astride the patient, face towards his head and so that his thighs are between your knees.

(3) Place the palms of your hands on the small of the patient's back, the little finger just touching the lowest rib, with the fingers held together and their tips just out of sight.

(4) With the arms held straight, swing forward slowly to the count of "one, two, three" so that the weight of your body is gradually brought to bear upon the lower ribs of the patient to force the air out of the patient's lungs.

(5) Without removing your palms from the small of the patient's back swing backward to the count of "four, five, six", removing all

Fig. 364. Second method of artificial respiration (air forced out of lungs)

pressure from the patient's body and thereby allowing the lungs to fill with air.

(6) After two seconds, swing forward again and repeat the cycle as long as necessary.

Another (Silvester) method of artificial respiration can be used when an assistant is at hand. To carry out this method (Fig. 364):

(1) Lay the patient flat on his back and place a roll of clothing under his shoulders to ensure that his head is thrown well back.

(2) Wipe saliva out of his mouth, pull the tongue forward and toward the chin and hold it in this position.

(3) Kneel at the patient's head and grasp his arms immediately below the elbows.

(4) Swing forward and press his arms steadily and firmly downwards and inwards against the sides of the chest to force the air out of the lungs.

(5) Bring the patient's arms steadily (to the count of "one, two, three") backwards until they are in line with the body and the elbows are almost touching the ground as in Fig. 365, thus allowing the lungs to fill with air.

(6) After three seconds swing forward again and repeat the cycle as long as necessary.

When two assistants are available, artificial respiration can be carried out by two persons, each standing on one knee at one side of the patient and acting as directed above, the third man holding the tongue of the patient pulled forward.

When artificial respiration is performed properly, the chest expands and contracts, and a sound like moaning due to the passage of air through the windpipe of the patient can be heard.

Recently still another method of artificial respiration has been coming into use. This method, which is a modification of mouth-to-mouth breathing, employs an appliance made from a flexible plastic or rubber tube 160 mm long and 8 to 12 mm in diameter

Fig. 365. Second method of artificial respiration (air inhaled)

which is cut in two, one piece 100 mm long, and the other 60 mm long. These pieces are joined by slipping them on a piece of metal or rigid-plastic tube 40 mm long. In the centre of the joint an oval flange $40 \times \times 115$ mm cut from dense rubber is fitted. This flange prevents free escape of the air from the patient's throat.

If the patient is not breathing, open his mouth and quickly insert the tube with the long end forward if he is an adult, and with the short end, if a child. In inserting the tube, see that the tongue has not fallen backward. Place the flange firmly over the mouth, and pinch the nostrils shut to prevent escape of the air blown in. Move the chin slightly up and down to straighten the tube in the mouth of the patient, and direct it into the windpipe. Blow one vigorous breath every five seconds into the tube to make the patient's chest rise.

This is not difficult or tiring. Experience has shown that a rescuer can easily maintain this breathing procedure for a half-hour or more. This period of time is sufficient to restore normal air exchange in the patient's lungs.

Exhalation by the patient may be aided by light pressure on his chest after an inhalation. See that the air does not go into his stomach. This may take place if the breathing tube has been inserted into the

gullet instead of the windpipe. If this happens, press upon the upper part of the belly below the diaphragm to expel the air.

When such a breathing tube is not on hand, act fast to insert your thumb into the mouth of the patient, pull his chin downward, pinch his nostrils shut, take a deep breath, place your mouth firmly over his mouth, and blow hard enough to make his chest rise, while holding the thumb between the two mouths. Watch for the patient's chest to expand in rhythm with the rate of respiration. If it does not, recheck the victim's head and jaw position and blow harder into his mouth. When the patient resumes breathing, assist him by continuing artificial respiration for some time until he fully revives.

Reviving apparatus. Recently a variety of reviving apparatus has been coming into use in cases of electric shock (stoppage of breathing, of the heart, the pulse). One of them is the ДП-1 apparatus. It is easy to operate and uses a mixture of air and oxygen. This apparatus is used in power stations, substations and industrial undertakings. It can be mounted on a wheeled carriage for mobility. It consists of a compressor which runs at a steady rate of 20 respiratory cycles per minute, an electric motor, and an oxygen cylinder. This apparatus operates from a lighting circuit or storage batteries. The gas mixture is delivered through a hose and a mask which is placed on the face of the patient.

Rocking stretchers. Several prototypes had been developed in the U.S.S.R. at this writing. For its operation, a rocking stretcher depends on the fact that when the patient is in the head-down position, the weight of the abdominal organs exerts pressure on the diaphragm, thereby compressing the lungs and causing exhalation. In the feet-down position, the abdomen pulls down the diaphragm, and the chest expands, thereby causing inhalation. The patient is rocked from a position of 45° above to 45° below the horizontal at below the normal rate of respiration. This method is accompanied with heart massaging and can be combined with oxygen reviving apparatus.

Special mention should be made of the defibrillator, an apparatus for reviving a patient from apparent death resulting from electric shock or other causes. This apparatus is portable, easy to use and very effective when reviving a shock victim within 7 or 8 minutes after the accident. This apparatus stops fibrillation of the heart, a very dangerous condition, when the heart is twitching instead of contracting normally to cause the blood to circulate.

LIST OF RUSSIAN-ENGLISH TRANSLITERATIONS OF SOME OF THE SOVIET SWITCHGEAR EQUIPMENT

Russian designation	English transliterations	Name and principal characteristics
		General
ЗРУ	ZRU (LSI)	Indoor substation
ОРУ	ORU (OSI)	Outdoor substation
РУ	RU	Switchgear installation (general term)
КСО	KSO	Prefabricated unit-type front-serviced switchgear (indoor)
КРУ	KRU	Factory-assembled metal-clad switchgear (indoor)
КРУН	KRUN	Factory-assembled metal-clad switchgear cubicle (outdoor)
АПВ	APV (ARC)	Automatic recloser or reclosing
		Insulators
П-3	P-3	Outdoor suspension insulator unit
ОА-6-кр	OA-6-kr	Post insulator—a 6-kv bus support, with round base fitting
ОА-6-ов	OA-6-ov	Post insulator—a 6-kv bus support, with oval base fitting
ОВ-6-кр	OV-6-kr	As above—V, strength rating
ОВ-10-кв	OV-10-kv	Post insulator—10-kv bus support with square base fitting
ОД-10-кв	OD-10-kv	As above—D, strength rating
ШН-6	ShN-6	Outdoor pin-type insulator, 6 kv
ШТ-35	ShT-35	Outdoor pin-type insulator, 35 kv
ИШД-35	IShD-35	Outdoor pin-type insulator, 35 kv
		Bushings
ПА-6/400	PA-6/400	Bushing—6 kv, 400 a, indoor type, A, strength rating
ПБ-10/600	PB-10/600	Bushing—10 kv, 600 a, indoor type, B, strength rating
ПВ-10/1000	PV-10/1000	Bushing—10 kv, 1,000 a, indoor type, V, strength rating
ИПШ-I-10	IPSh-I-10	Bus-type bushing—10 kv, I, strength rating
ПНБ-6/400	PNB-6/400	Outdoor bushing, 6 kv, 400 a, B, strength rating
ПНВ-10/1000	PNV-10/1000	Outdoor bushing, 10 kv, 1,000 a, V, strength rating
МН-110	MN-110	Outdoor oil-filled bushing, 110 kv

Russian designation	English transliterations	Name and principal characteristics
		Isolators
РВО-6/400	RVO-6/400	Isolator, indoor, 6 kv, 400 a, single-pole
РЛВО-10/1000	RLVO-10/1000	Isolator, indoor, line, 10 kv, 1,000 a, single-pole
РВТ-10/1000	RVT-10/1000	Isolator, indoor, 10 kv, 1,000 a, three-pole
РВК-10/4000	RVK-10/4000	Isolator, indoor, 10 kv, 4,000 a, with box-shaped blade
ВН-16	VN-16	On-load isolator
ВНП-16	VNP-16	On-load isolator (fuse-switch)
РЛН-35/1000	RLN-35/1000	Isolator, line, outdoor, 35 kv, 1,000 a
РЛНЗ-35/600	RLNZ-35/600	Isolator, line, outdoor, 35 kv, 600 a, with earthing blades
		Circuit Breakers
ВГ-10	VG-10	Hard-gas circuit breakers, 10 kv, up to 400 a
ВМБ-10	VMB-10	Oil circuit breaker, 10 kv, 200 to 1,000 a, single-tank type
ВМГ-133	VMG-133	Circuit breaker, minimum-oil, multiple single-pole, 10 kv, up to 600 a
МГГ-10	MGG-10	Minimum-oil type circuit breaker, 10 kv, 2,000 and 3,000 a (for generator circuits)
МГГ-229	MGG-229	Minimum-oil type circuit breaker, generator circuit, for large currents (up to 5,000 a)
ВМ-35	VM-35	35-k outdoor circuit breaker
ВМД-35	VMD-35	35-kv outdoor circuit breaker with bushing transformers for differential protection
МКП-35	MKP-35	Outdoor oil circuit breaker, substation type
МГ-35	MG-35	35-kv oil circuit breaker, multiple single-pole type
МКП-110	MKP-110	110-kv, bulk-oil substation oil circuit breaker (outdoor)
ВВН-110	VVN-110	110-kv. air-blast circuit breaker (outdoor)
		High-voltage Fuses
ПК-6/150	PK-6/150	High-voltage fuse, quartz-sand filled, for power circuits, 6 kv, 150 a
ПКТ-10	PKT-10	High-voltage, voltage transformer fuse, 10 kv
		Current Transformers
ТПФ	TPF	Current transformer, bushing type. porcelain insulated
ТПФМ	TPFM	Same as above, modernised version

Continued

Russian designation	English transliterations	Name and principal characteristics
ТПОФ	TPOF	Current transformer, single-turn, porcelain-insulated
ТПШФ	TPShF	Current transformer, bus type, porcelain-insulated
ТФН	TFN	Current transformer, porcelain-insulated, outdoor
		Voltage (Potential) Transformers
НОМ-6	NOM-6	Voltage transformer, single-phase, oil-immersed, 6 kv
НТМК-10	NTMK-10	Voltage transformer, three-phase, oil-immersed, with compensating winding, 10 kv
НТМИ-10	NTMI-10	Voltage transformer, three-phase oil-immersed, with testing winding
НКФ-110	NKF-110	Voltage transformer, cascade-type, porcelain-insulated, outdoor
		Construction Electrician's Accessories
СМП-1	MP-1	Powder-actuated dowel-driving gun
НГП-7	NGP 7	Foot-operated hydraulic press
УПП	UPP	Universal portable press
ПН-1	PN-1	Press-shear unit (motor driven)
ПРН-5	PRN-5	Hand-operated lever-arm press
ЭЗС	EZS	Electric tool grinder
		Switchgear Accessories. Etc.
ПР-2	PR-2	Lever-type operating mechanism for isolators
КСА	KSA	Auxiliary switch for switchgear signal and interlock contacts)
ПК	PK	High-voltage quartz-sand-filled power-circuit fuse
ПКТ	PKT	High-voltage fuse for voltage transformers (T)
ПРА-12	PRA-12	Lever-type operating mechanism, for on-load isolators
ППР-12	PPR-12	Spring-loaded lever-type operating mechanism
ПР-3В	PR-3V	Spring loader used with PPR-12 mechanism
ПРА-10	PRA-10	Operating mechanism, hand-operated, automatic tripping
ПРБА	PRBA	Operating mechanism, hand-operated, automatic tripping

TO THE READER

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